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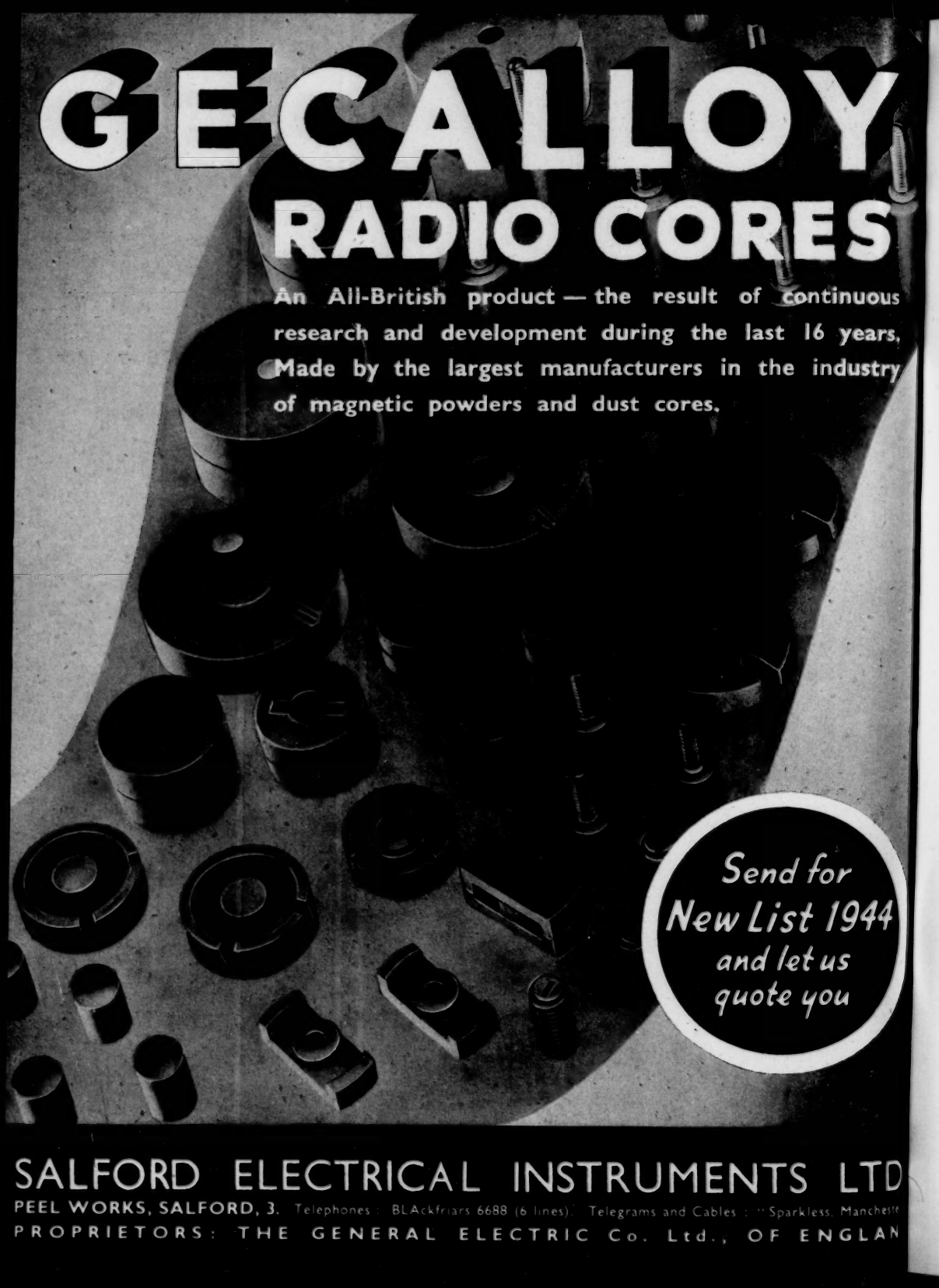
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Editor HUGH S. POCOCK, M.I.E.E. Technical Editor Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

VOL. XXII APRIL, 1945 No. 259

EDITORIAL

The Radiation Resistance of a Half-Wave Dipole Aerial

THIS Editorial contains no new discovery but describes step by step the calculation from fundamental principles of the radiation resistance of a half-wave dipole aerial or of a quarter-wave vertical earthed aerial. It is hoped that it will prove of interest to those engaged in teaching the fundamental principles of radio telegraphy.

We assume in Fig. 1 that a positive charge q was moving steadily upwards with a velocity v and that, if nothing had happened, it would have been at C at the moment considered; CDE would have been one of its lines of electric force. But something did happen, for at a time t before the moment considered, when the charge was at A it slowed down with uniform deceleration and came to rest at B. That this has happened cannot yet be known beyond a sphere of radius ct where c is the velocity of light. A sphere of this radius about A passes through D and the line of force CDE only exists beyond D. If the time taken to slow down and come to rest was T, the distance $AB = Tv/2$. At the moment considered a time $t - T$ has elapsed since the charge came to rest at B, and a sphere about B of radius $c(t - T)$ represents the limit of the knowledge of this fact; within this sphere the field radiates from B. At the moment considered the line of force which would have followed the path CDE follows the path $BFDE$, the portion FD being straight because we assumed uniform deceleration. Since v is assumed to be small compared with c, the eccentricity AB of the two spheres $(= vT/2)$ is small compared with the difference cT between their radii. Hence the spherical shell is approximately concentric, of mean radius $r = c\left(t - \frac{T}{2}\right)$ and of thickness cT; it expands with the velocity of light.

The tangential component of FD is equal to CG and therefore to $BC \sin\theta$; the radial component, if drawn to scale, is indistinguishable from the radial thickness of the shell, viz., cT. Hence

$$\frac{\mathfrak{S}_t}{\mathfrak{S}_r} = \frac{BC \sin\theta}{cT}$$

Since the radial field $\mathfrak{S}_r = q/r^2$ and $BC = v\left(t - \frac{T}{2}\right)$

$$\mathfrak{S}_t = \frac{q}{r^2} \cdot \frac{v\left(t - \frac{T}{2}\right)}{cT} \cdot \sin\theta$$

$$= \frac{q}{c^2 r} \cdot \frac{v}{T} \cdot \sin\theta = -\frac{q}{c^2 r} \cdot \left(\frac{dv}{dt}\right) \sin\theta$$

Hence the radiated tangential field is inversely proportional to the distance, directly

proportional to the charge and to its acceleration, and positive, i.e. upwards, when the upward acceleration is negative. With a negative charge the field would be, of course, in the opposite direction.

That the electric field is associated with a magnetic field can be shown as follows, and a proof obtained that the velocity with which the shell expands is really equal to c as stated above. We assume provisionally that it expands with some unknown velocity x, and consider the small rectangular path $abcd$ one side only of which is in the field. The line integral of $\mathfrak{E}$ around this rectangle in the direction $abcd$ is $-\mathfrak{E}_t \,.\, cd$ and this must equal $-d\Phi/dt$ where Φ is the magnetic flux coming towards us through the rectangle. If B be the flux density in the shell, $-d\Phi/dt = -B \,.\, cd \,.\, \times x$; hence $\mathfrak{E}_t cd = B \,.\, cd \,.\, x$ where $\mathfrak{E}_t$ is in e.m. units. If $\mathfrak{E}_t$ is in e.s. units $\mathfrak{E}_t = Bx/c = \mu Hx/c$.

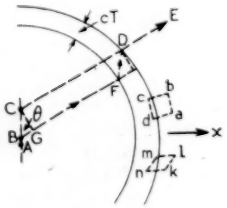


Fig. 1.

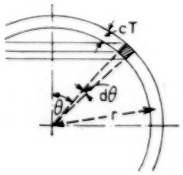


Fig. 2.

Similarly the m.m.f., that is, the line integral of H around the rectangle $klmn$, which is normal to the direction of $\mathfrak{E}_t$ and of which only the side mn is in the shell, is equal to 4π times the current through the path in e.m. units. The electric force $\mathfrak{E}_t$ produces an upward electric displacement D_t equal to $\kappa\mathfrak{E}_t/4\pi$ and the current through the area $klmn$ is equal to $(\kappa\mathfrak{E}_t/4\pi)\ mn \,.\, x/c$ e.m. units. Hence $H \,.\, mn = \kappa\mathfrak{E}_t \,.\, mn \,.\, x/c$ and we have the two equations

$$\mathfrak{E}_t = \mu Hx/c$$
$$H = \kappa\mathfrak{E}_t x/c$$

from which it follows that the velocity $x = c/\sqrt{\mu\kappa} = c$, since in the present case μ and κ are unity, and that $H = \mathfrak{E}_t\sqrt{\frac{\kappa}{\mu}} = \mathfrak{E}_t$ where $\mathfrak{E}_t$ is in e.s. units.

We shall now drop the suffix and represent the tangential field by $\mathfrak{E}$.

The electric and magnetic energies per cm^3 are $\mathfrak{E}^2/8\pi$ and $H^2/8\pi$ ergs respectively; hence the total radiated energy in a cubic centimetre of the shell is

$$\frac{1}{8\pi}(\mathfrak{E}^2 + H^2) = \mathfrak{E}^2/4\pi = \frac{q^2v^2\sin^2\theta}{4\pi c^4r^2T^2}$$

The energy in the narrow zone shown in Fig. 2

$$= \frac{q^2v^2\sin^2\theta}{4\pi c^4r^2T^2} \,.\, r\,d\theta \,.\, cT \,.\, 2\pi r\sin\theta$$

and that in the whole shell

$$= \frac{q^2v^2}{2c^3T}\int_0^\pi \sin^3\theta\,d\theta = \frac{2}{3}\frac{q^2v^2}{c^3T}\text{ ergs.}$$

This energy was radiated in a time T; hence the rate of energy radiation

$$= \frac{2}{3}\frac{q^2}{c^3}\left(\frac{dv}{dt}\right)^2 \text{ ergs/sec.}$$

If instead of moving uniformly until it arrived at A, as we assumed in Fig. 1, the charge had started from H with uniform acceleration, reached the velocity v at A and then decelerated as before, the shell would have been of twice the radial thickness and the path of the line of force would have been as shown in Fig. 3.

Single Oscillating Charge

If instead of a uniformly decelerated charge we have a charge oscillating up and down so that its distance s above its mid-position is given by the formula $s = \frac{l}{2}\sin\omega t$.

Then $$\frac{dv}{dt} = -\frac{l\omega^2}{2}\sin\omega t$$

and

$$\mathfrak{E} = H = \frac{q}{c^2r} \,.\, \frac{l\omega^2}{2} \,.\, \sin\theta \,.\, \sin\omega\left(t - \frac{r}{c}\right)$$

where $\frac{r}{c}$ is the time taken for the radiation to travel from the oscillating charge to the point considered at distance r. Also the rate of energy radiation $= \frac{2}{3}\frac{q^2}{c^3} \,.\, \frac{l^2\omega^4}{4}\sin^2\omega t$ and since the average value of $\sin^2\omega t = 0.5$ the average rate of energy radiation $= \frac{q^2l^2\omega^4}{12c^3}$ ergs per second. Fig. 4 illustrates one half-cycle of such an oscillation.

Oscillating Dipole

If two equal and opposite charges $+q$ and $-q$ oscillate over the same path so that their distances from the mid-point are always

equal and opposite, the effect is equivalent to doubling q and we have

$$\mathcal{E} = H = \frac{ql\omega^2}{c^2 r} \sin\theta$$

neglecting the phase of the wave, and the average radiated power

$$= \frac{q^2 l^2 \omega^4}{3c^3} \text{ ergs per second.}$$

In this case the radial fields due to the two opposite charges are equal and opposite and, except in the immediate neighbourhood of the dipole, there is no field outside the expanding shell.

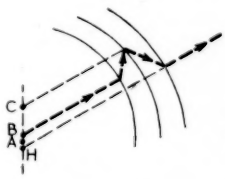


Fig. 3.

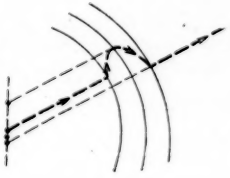


Fig. 4.

Hertzian Oscillator with Large End Capacitance

In this case we assume the current to be the same at all points of the wire of length l joining the end plates. At the moment of zero current we have charges of $+\hat{q}$ and $-\hat{q}$ separated by a distance l as in the foregoing case, except that $\hat{q}$ now replaces the oscillating charge q.

If we put $q = \hat{q} \sin \omega t$ we have

$$i = \frac{10}{c}\frac{dq}{dt} = \frac{10}{c}\omega\hat{q}\cos\omega t \quad \text{and} \quad \hat{\imath} = \frac{10}{c}\omega\hat{q}$$

where i is in amperes and q in e.s. units.

Substituting for q in the above formulae we have

$$\mathcal{E} = H = \frac{\hat{\imath} l\omega}{10cr} \sin\theta = \frac{2\pi}{10} \cdot \hat{\imath} \cdot \frac{l}{\lambda} \cdot \frac{\sin\theta}{r}$$

and the average radiated power

$$= \frac{\hat{\imath}^2 l^2 \omega^2}{300c} \text{ ergs./sec.} = \frac{I^2 l^2 \omega^2}{150\,c} \text{ where } I \text{ is the r.m.s. current.}$$

Putting $\omega = 2\pi c/\lambda$, this becomes $789 \frac{l^2}{\lambda^2} I^2$ watts.

This formula involves an assumption which in many cases is fully justified, but not in all, viz., that the phase differences between the effects at any distant point due to the different portions of the aerial are negligible, and that one is therefore justified in simply adding the effects, or in other words, that to find $\mathcal{E}$ or H at any point it is only necessary to find the value due to 1 cm. of the aerial and multiply it by the effective length. If the current is not of the same magnitude along the aerial, the effective length is the same fraction of the total length as the mean current is of the current at the point of measurement.

Earthed Vertical Aerial with Large Upper Capacitance

Such an aerial together with its image constitutes a Hertzian oscillator of length $l = 2h$ where h is the height of the aerial; hence

$$\mathcal{E} = H = \frac{4\pi}{10} \cdot \hat{\imath} \cdot \frac{h}{\lambda} \cdot \frac{\sin\theta}{r}$$

and the radiated power (in the upper hemisphere only) is equal to $1578 \left(\frac{h}{\lambda}\right)^2 I^2$ watts.

Half-wave Dipole

If the end capacitances are removed from the Hertzian oscillator the current at the ends must be zero, and when tuned to resonance at its fundamental frequency the current distribution will be approximately sinusoidal. The same is true of a quarter-wave earthed vertical aerial. In the equatorial plane of such an aerial the field strength $\mathcal{E}$ is correctly given by the above formula if the effective length is taken as $2l/\pi$ since the effects of all parts of the aerial arrive in phase and can be simply added. In other directions, however, this is no longer approximately true, and the phase differences must be taken into account. If in Fig. 5 the current at the mid-point be taken as unity, the current at a distance x from the mid-point will be $\cos 2\pi x/\lambda$, and the field due to the element dx in the direction shown will arrive out of phase with that due to the centre by an angle $\phi = (2\pi x/\lambda)\cos\theta$.

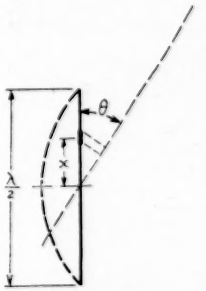


Fig. 5.

Its effective component will be

$$\cos 2\pi x/\lambda \times \cos \phi = \cos 2\pi x/\lambda \times \cos \left[(2\pi x/\lambda) \cos \theta\right]$$
$$= \tfrac{1}{2} \cos \left[(2\pi x/\lambda)(1 + \cos \theta)\right] + \tfrac{1}{2} \cos \left[(2\pi x/\lambda)(1 - \cos \theta)\right]$$

Integrating this expression from

$$x = -\lambda/4 \text{ to } x = +\lambda/4$$

we get*

$$\frac{\lambda}{\pi} \frac{\cos[(\pi/2)\cos\theta]}{\sin^2 \theta}$$

If $\theta = 90°$, i.e. in the equatorial plane, this is equal to λ/π, that is, the mean current $2/\pi$ multiplied by the length $\lambda/2$.

In other directions the field strength is not simply reduced in the ratio $\sin \theta$ but in the ratio

$$\sin \theta \times \frac{\cos[(\pi/2)\cos\theta]}{\sin^2 \theta} = \frac{\cos[(\pi/2)\cos\theta]}{\sin \theta}$$

The energy per cm³ at a given distance, which is proportional to $\mathfrak{E}^2$, instead of varying as $\sin^2 \theta$ will vary as $\frac{\cos^2[(\pi/2)\cos\theta]}{\sin^2 \theta}$, and the energy in an elemental zone as shown in Fig. 2, instead of varying as $\sin^3 \theta$ will vary as $\frac{\cos^2[(\pi/2)\cos\theta]}{\sin \theta}$. This then is the expression that must be integrated between 0 and π instead of $\sin^3 \theta$ in order to find the energy in the whole shell. Its values are plotted in Fig. 6 which also gives the values of $\sin^3 \theta$ for comparison. They are also given in the above table.

---

*$$\int_0^{\lambda/4} \cos[(2\pi x/\lambda)(1+\cos\theta)]\,dx + \int_0^{\lambda/4} \cos[(2\pi x/\lambda)(1-\cos\theta)]\,dx$$
$$= \left[\frac{\sin(2\pi x/\lambda)(1+\cos\theta)}{(2\pi/\lambda)(1+\cos\theta)} + \frac{\sin(2\pi x/\lambda)(1-\cos\theta)}{(2\pi/\lambda)(1-\cos\theta)}\right]_0^{\lambda/4}$$
$$= \frac{\sin\frac{\pi}{2}(1+\cos\theta)}{(2\pi/\lambda)(1+\cos\theta)} + \frac{\sin\frac{\pi}{2}(1-\cos\theta)}{(2\pi/\lambda)(1-\cos\theta)}$$
$$= \frac{\lambda}{2\pi}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{1+\cos\theta} + \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{1-\cos\theta}\right]$$
$$= \frac{\lambda\cos\left(\frac{\pi}{2}\cos\theta\right)}{2\pi}\left(\frac{2}{1-\cos^2\theta}\right)$$
$$= \frac{\lambda}{\pi}\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}$$

θ	10°	20°	30°	40°
$\sin^3\theta$	0.005	0.04	0.125	0.266
$\frac{\cos^2[(\pi/2)\cos\theta]}{\sin\theta}$	0.003	0.026	0.088	0.20

θ	50°	60°	70°	80°
$\sin^3\theta$	0.45	0.65	0.83	0.955
$\frac{\cos^2[(\pi/2)\cos\theta]}{\sin\theta}$	0.37	0.577	0.785	0.942

By applying Simpson's rule to these values the mean value of $\frac{\cos^2[(\pi/2)\cos\theta]}{\sin\theta}$ is found to be 0.388 whereas the mean value of $\sin^3\theta$ is $4/3\pi = 0.424$. Hence the effect of the phase difference is to reduce the radiated power in the ratio 0.388/0.424 which is 0.915.

We found that for a Hertzian oscillator the radiated power was

$$789 \frac{l^2}{\lambda^2} I^2 \text{ watts.}$$

Putting the mean current equal to $2I/\pi$ and $l = \lambda/2$ gives $789\ I^2/\pi^2$ which is exactly 80 I^2 watts. To allow for the effect of phase difference this has to be multiplied

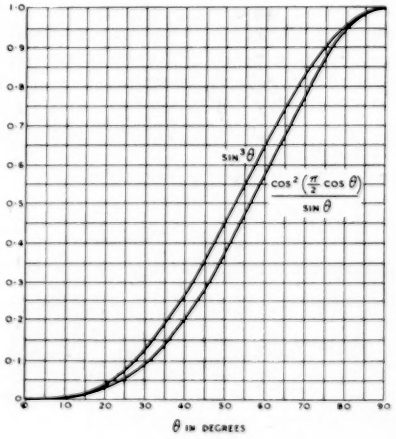


Fig. 6.

by 0.915 which gives a radiated power of 73.2 I^2 watts. Hence the effect of the phase difference is to reduce the radiation resistance of the half-wave dipole from 80 to 73.2 ohms. In the case of a quarter-wave earthed aerial these figures become 40 and 36.6 ohms.

G. W. O. H.

SPACE CHARGE EFFECTS

Between a Positive Grid and Anode of a Beam Tetrode*

By G. B. Walker, M.A.

SUMMARY.—A theoretical study is made of the effects of space charge between the screen grid and anode of the beam tetrode. Account is taken of the deflections acquired by the electrons on crossing the screen grid and the electron stream is assumed to consist of charged particles whose motions differ. The distribution of velocity among the electrons is considered and means are given whereby the current passed to the anode may be related to the anode voltage. In this way an attempt is made to explain certain features in the performance of the valve. The paper is in three parts. In the first the principal effects of space charge are reviewed, a study is made of the trajectories of electrons in the valve and the primary effect of space charge discussed. In the second part a general treatment of the electric field is attempted, and the fact emerges that for a given set of applied voltages there can be more than one possible distribution of potential and space charge in the valve. Herein is a likely explanation for a certain instability phenomenon which may be observed in actual valves. In the first two parts the problem is simplified by the assumptions :—

(*a*) That in the electron beam the electric force is directed toward the anode, i.e., there is no spreading in the beam.

(*b*) That the current crossing the screen grid in the anode direction is independent of the anode voltage.

(*c*) That there is no secondary emission.

In practice none of these is completely satisfied, and in the third part their importance to the working of the valve is considered.

Principal Symbols

I = current crossing the screen grid in the anode direction.
i = current density.
J = current per unit depth of the beam.
I_a = current collected by the anode.
ρ = space charge density.
e = charge of an electron.
m = mass of an electron.
V = voltage at any point.
V_a = anode voltage.
V_{gn} = applied voltage on nth grid.
V_g = effective potential at the screen grid.
V_K = " knee " anode voltage.
V_T = " turn " potential.
V_m = voltage at the potential minimum.
v = total speed of an electron.
v_t = greatest tangential velocity component of an electron.
v_n = normal velocity component of an electron.
$x_{n,\,n+1}$ = spacing between grids n and $n+1$, measured from the centre of the wires.
p_n = pitch of the nth grid.
d_n = wire diameter of the nth grid.
μ_n = amplification factor of the nth component triode.
x_g = distance from the screen grid to the potential minimum.
x_a = distance from the potential minimum to the anode.
l = emitting length of cathode.
b = emitting breadth of cathode.
A = emitting area of cathode.
$\alpha = V_m/V_T$.
lnx = natural logarithm of x.
$erfx$ = the Error Function, defined as:

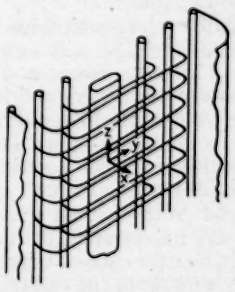
$$\frac{2}{\sqrt{\pi}}\int_0^x \exp.\ (-x^2)\ dx.$$

All other functions defined in the text.

PART I

Introduction

SPACE charge effects beyond a positive grid have acquired a new importance in the last few years, for, with recent advances in constructional technique, much higher current densities are used and the functioning of many modern valves depends very largely on the behaviour of space charge other than at the cathode. For example, there is a region between grids 2 and 3 in the hexode in which the charge density may become relatively high and the control characteristic of the latter grid is influenced appreciably by such charge.



Location of axes is as shown in this figure.

So far as the writer is aware only simple cases of space charge have been treated and there is a very urgent need for further information, both qualitative and quantitative, on the effects which arise in an actual valve.

* MS. accepted by the Editor, November, 1944.

The most important omission in previous theories is that no account is taken of the trajectories of the electrons, and writers tend to over-simplify the problem by the assumption that electrons cross a positive grid all with the same velocity directed normally to the grid. This quite definitely is not true in practice, nor is it even approximately so, and the primary concern of the paper is to analyse space charge in beams formed by electrons whose motions differ.

Rather than give a general treatment we shall limit the discussion to the beam tetrode for it is in this valve that the effects of space charge are to be observed most clearly. As far as possible we have avoided mathematical intricacies which have no immediate bearing on specific design problems, and all calculations are intended to illustrate and explain physical principles. In this sense the treatment is not rigorous and although we attempt no more than a simple analysis of a particular valve type, it is hoped that the findings may throw some light on the behaviour of electrons in other valves and that the method of attack may prove to have wider applications.

General Survey

Let us begin with a review of the principal features in the performance of a beam tetrode which may be seen in the typical family of $I_a - V_a$ characteristic curves, Fig. 1. These curves were obtained by applying an oscillatory voltage of 400 c/s to the anode of the valve, all other voltages being fixed, and the instantaneous values of anode current and anode voltage recorded by means of a cathode-ray tube*.

In no case is the anode current maintained at a low value of anode voltage and each curve has a distinct " knee." The use of the term " knee " is purely descriptive and it will be noted that the form of the knee alters considerably throughout the family of curves.

The value of the control grid bias (marked on each curve), specifies the amount of current which approaches the screen grid, for this current is nearly independent of the anode voltage. It is in fact the current which would be measured by a meter in the cathode lead and will be called the cathode current.

At very negative values of control bias, i.e., at low values of cathode current, a decided " kink " is to be observed in the anode current characteristic near the knee, but as the cathode current is increased this kink disappears and the knee moves to the right. The form of the knee becomes less rounded as the cathode current is further increased, till finally the curve appears to be discontinuous.

An explanation of the " kink " is not hard to find, for writers are in agreement that it is due to the emission of secondary electrons from the anode. Such emission can occur at bombarding voltages as low as 10 volts, and secondary electrons released under these conditions are able to reach the screen thereby detracting from the anode current.

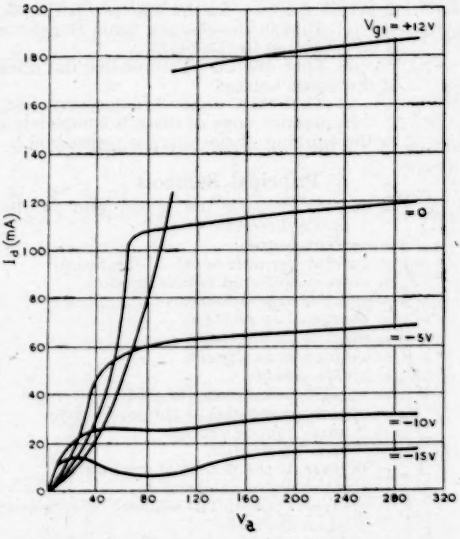


Fig. 1. *Typical $I_a - V_a$ characteristic curves for the beam tetrode.*

It is unnecessary to stress the undesirability of any irregularity in the anode current characteristic brought about in this way, and the suppression of secondary emission is an urgent problem to the valve designer.

In general terms it can be accomplished by the production of a region between the screen and anode at a potential less than that of the anode, so that secondaries from the latter move into a retarding field and are returned, but we shall have more to say on this later and for the time we shall

*For further details see " Testing Amplifier Output Valves by means of the Cathode Ray Tube." A. J. Heins van der Ven. *Philips Tech. Rev.*, March 1940, Vol. 5, No. 3, page 61.

assume that secondary emission does not occur.

It is to the knee that we must first devote our attention, for this fundamental feature in the characteristic of a valve has been rather overlooked in the past, and it is necessary to come to an understanding of the underlying mechanism if space charge effects are properly to be appreciated. The cause of the knee is to be found in the trajectories of electrons in the valve and it is not brought about by space charge as such.

At high anode voltages all electrons which succeed in crossing the screen grid continue to the anode and are collected there, but as the anode voltage is reduced the available current to the anode is also reduced for two main reasons :

(a) The field strength at the cathode suffers a slight decrease since it cannot be completely independent of the anode voltage ;

(b) The fraction of the cathode current taken by the screen is increased.

The latter effect comes about because the configuration of the electric field at the screen alters in such a way that more electrons are attracted to the wires of the screen. Both effects are quite small and the net result is the observed gradual decrease in anode current. When the anode voltage reaches a certain critical value a change takes place, certain of the electrons which cross the screen fail to reach the anode and are reflected back, eventually to be collected by the screen. This marks the onset of the knee, for, as the anode voltage is reduced further, more and more electrons are returned to the screen and the anode current soon dies to zero.

In what follows we shall identify the knee anode voltage V_K with that voltage at which electrons begin to be reflected back to the screen.

The importance of space charge lies in the way it modifies the electric field in the screen-anode region, thereby affecting electron reflections. As a primary effect we have seen that by increasing the current (and hence the space charge) the knee is made to occur at higher anode voltage values. The discontinuity at the knee which we remarked at very high current values is also to be explained in terms of space charge, the proper treatment of which is the subject of a later section. We may remark here that under the conditions of the case there is more than one possible potential distribution over a limited range of anode voltage near the knee and in this range a sudden change can occur in the distribution of space charge, involving a change in the current reaching the anode. The valve is unstable over the range and we shall refer to the anode current discontinuity as an instability effect.

In making calculations on the effects mentioned above we shall treat all electrodes as being of planar form. This is very necessary if the matter is to remain in a manageable form, and it does not impose a serious restriction since it is customary in the beam tetrode for electrodes to be planar at least within the boundary of the electron beam.

The nature of the beam presents a formidable difficulty and we shall only speculate on its probable form. It is usual to introduce earthed plates called " beaming plates " between the screen and anode to assist the formation of a beam, but their chief function is to prevent the straying of electrons at the edge of the beam and they have very little effect at the centre.

Calculations will first be made on the assumption that there are no edge effects, that is, that the beam is uniform over any section parallel to the anode, as would be true over a central portion in a very broad beam and later we shall endeavour to indicate the changes which are required in the treatment of the type of beam normally used in practice, in which there is appreciable spreading.

The Mechanism of the Knee

We have identified the knee with that anode voltage at which electrons begin to be reflected back to the screen ; we shall now endeavour to illustrate the process of reflection and, to that end, study the trajectories of electrons in a planar triode in which the grid is held at a positive voltage (with respect to the cathode).

Some electrons will pass mid-way between two wires of the grid and will continue on directly toward the anode as shown in path 1 (Fig. 2). Others passing not quite mid-way between the wires will be deflected toward the nearer wire as shown in path 2. The most important for our purpose are those electrons which receive the greatest deflection on passing the grid, for it is they that determine the onset of the knee. They will be termed m.d. electrons (m.d. standing

for " most deflected.") Other electrons as in path 4 will go directly to the grid and contribute to the grid current.

The electric field in the neighbourhood of the grid is of a complicated structure but we may assume that at a short distance beyond the grid the field evens out and

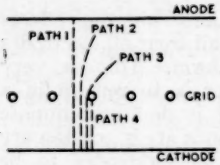


Fig. 2.—*Section of a triode showing electron trajectories when the grid is positive with respect to the cathode.*

becomes uniform, directed toward the anode. The m.d. electrons in being deflected at the grid acquire a transverse velocity component parallel to the anode and we shall assume that they enter the uniform part of the field with a transverse velocity component v_t which remains constant throughout the further movement to the anode.

Let the normal velocity component be v_n and the resultant velocity be v, then :

$$v^2 = v_t^2 + v_n^2 \quad .. \quad .. \quad .. \quad (1)$$

If now we take the cathode voltage as zero and assume that the electrons leave with no initial velocity, the equation of energy is :

$$\tfrac{1}{2}mv^2 = eV \quad .. \quad .. \quad .. \quad .. \quad (2)$$

where V is the potential at the point where a particular electron happens to be.

From equations (1) and (2) it follows that :—

$$\tfrac{1}{2}m(v_t^2 + v_n^2) = eV$$

$$\therefore \qquad v_n^2 = \frac{2e}{m} \cdot V - v_t^2 \quad .. \quad (3)$$

There will, therefore, be a certain positive voltage V_T where v_n becomes zero. This is given by the equation :

$$0 = \frac{2e}{m} \cdot V_T - v_t^2$$

$$\text{or} \quad V_T = \tfrac{1}{2} \cdot \frac{m}{e} \cdot v_t^2 \quad .. \quad .. \quad .. \quad (4)$$

When a m.d. electron going toward the anode reaches a plane where the voltage is V_T it will have lost all its forward velocity component. It therefore turns back toward the grid, and must eventually be collected by the grid. V_T will be termed the " turn potential " and is fundamental in the following treatment.

We may remark that V_T is always less than the voltage at the grid, as is implied in the fact that the m.d. electrons succeed in crossing the grid. When the current passed by the valve is so slight that the electric field is not modified by space charge and the anode voltage is greater than V_T there can be no plane between the grid and anode at a potential less than, or equal to, V_T, thus all electrons which cross the grid must reach the anode. If on the other hand V_a is less than V_T there must be a plane at potential V_T between the grid and anode and a certain fraction of the current will be returned to the grid, the reflections occurring between this plane and the anode. The critical case is when $V_a = V_T$ for this is the anode voltage at which m.d. electrons turn back just at the surface of the anode. Consequently we may assume that the knee commences here and write $V_K = V_T$.

Generalising from this result we may state that a criterion for the onset of the knee in the anode current characteristic curve is that the lowest potential between the grid and anode has the value V_T.

In Appendix 1 an expression for the tangential velocity component acquired by an m.d. electron in a positive grid triode is derived, namely :—

$$v_t = \sqrt{\frac{2e}{mV_g}} \cdot \pi \cdot \lambda \cdot \left[1 - \frac{r}{\pi} \cdot ln\,\frac{r}{4}\right] \quad (5)$$

whence :

$$V_T = \frac{1}{V_g}\left\{\pi \cdot \lambda \cdot \left[1 - \frac{r}{\pi} \cdot ln\,\frac{r}{4}\right]\right\}^2 \quad .. \quad (6)$$

The step from the triode to the tetrode is a small one, for the introduction of a control grid makes very little difference to the tangential velocity acquired at the screen. It is true that electrons may receive very large deflections at the control grid, but since the potential there is low, tangential velocity components acquired must be small compared with those acquired on crossing the screen. We shall treat the control grid merely as an electron source and modify the above expression accordingly. Whence :

$$V_K = V_T \doteq V_{g2}\left\{\frac{p_2\mu_2(x_{12} + x_{2a})\left[1 - \dfrac{d_2}{2\pi x_{12}} \cdot ln\,\dfrac{d_2}{8x_{12}}\right]}{4x_{2a}(x_{12} + x_{2a} + \mu_2 x_{12})}\right\}^2$$
$$.. \quad .. \quad (7)$$

where μ_2 is the amplification factor of a hypothetical triode whose cathode coincides with the control grid.

The accuracy of these formulae for v_t and V_T is not the primary concern of this paper,

and it is difficult to obtain satisfactory experimental verification due to the effects of secondary emission already mentioned.

On the whole the agreement between the calculated value of V_K and that suggested by the valve characteristic appears to be quite good and by way of illustration the curves in Fig. 3 are given. The relevant dimensions of the valve on which the curves

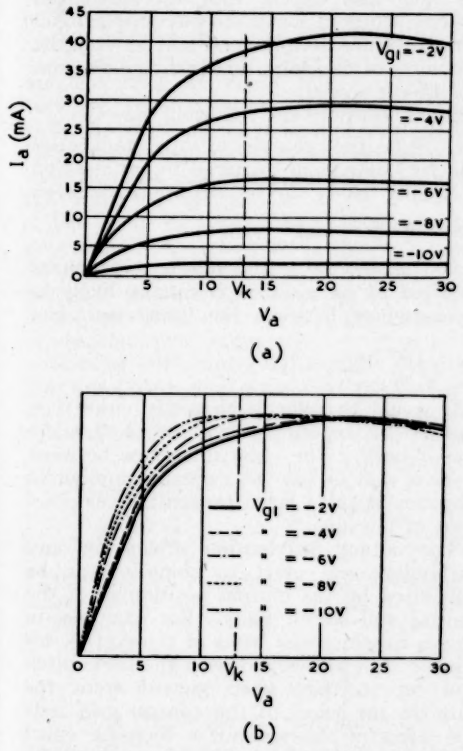


Fig. 3.—(*a*) $I_a - V_a$ *characteristic curves for valve* (1). (*b*) *These are the same curves as in* (*a*) *except that the current scales of the lower curves have been increased so that the form of the knee may more easily be compared throughout the set.*

were taken are given in Table I and the line V_K was calculated from equation (7).

TABLE I

$x_{01} = 0.313$;	$x_{12} = 1.323$;	$x_{20} = 4.89$
$p_1 = 0.44$;	$p_2 = 1.15$	
$d_1 = 0.060$;	$d_2 = 0.080$	

$V_T = 13$ volts ; $V_{g2} = 250$ volts.

Further evidence in support of the theory can be obtained by the use of the " rubber model." This device has been described elsewhere and its application to the problem in hand was given by Jonker in the *Philips Technical Review*, 1940.

Outline of the Space Charge

We shall now examine the effects of space charge in the screen grid-anode region of the beam tetrode.

It has been shown* that at charge densities of the order to be expected in ordinary valves the mean free path of an electron is so great that collisions can safely be disregarded, although the actual distance between neighbouring electrons is infinitesimal compared with the dimensions of the valve.

In so far as the electric field is concerned we are at liberty to treat space charge as if it were continuous, but at the same time we must recognise that the electron stream is composed of charged particles whose motions differ.

Let us assume that, except near the screen, the electric field (containing space charge) is directed normally to the anode, so that over any plane parallel to the anode the potential is constant. The actual trajectory of any particular electron need not concern us, but it is important to postulate that, as in the space-charge-free case, tangential velocity components acquired on crossing the screen are preserved in the subsequent motion. To estimate the space charge density at any point we need only refer to the normal velocity components of the electrons, for by symmetry we can assume that there are as many electrons with tangential components in one direction as in the reverse, and with the intermingling of electrons we shall take it that the composition of the current is constant over any plane parallel to the anode.

Let di be that part of the total current crossing a unit area composed of electrons with normal velocity between v_n and $(v_n + dv_n)$ then the contribution to the total space charge density is : $d\rho = \dfrac{di}{v_n}$

and so† $\rho = \displaystyle\int \frac{di}{v_n}$ .. .. .. (8)

* See for example " Electrical Discharges in Gases." I. Langmuir and K. T. Compton. *Reviews of Modern Physics*, April 1931, Vol. 3. No. 2, page 218.

† In these equations v_n is a scalar quantity, for it makes no difference to the density if an electron is moving toward or away from the anode.

The Velocity Distribution

Let us now investigate v_n.

While studying the knee we made the assumption that electrons leave the cathode with zero initial velocity, so that the total speed v of an electron at a point at potential V is given by the energy relation :

$$\tfrac{1}{2} \cdot mv^2 = eV$$

This is not quite correct for it is well established on both theoretical and experimental evidence that electrons leave the cathode with a velocity distribution which is approximately Maxwellian. It has been shown by Langmuir * and others that only a small fraction (less than 1 per cent.) of the electrons emitted from a cathode at a normal working temperature have emission velocities greater than would be generated by a fall through 1 volt. It will become clear later that the most important electrons are those with low forward velocity, and that the very small group of high velocity electrons make an insignificant contribution to the space charge density in the screen-anode region. The matter is not without interest, and we shall give a calculation of space charge density including the effect of the emission velocity distribution in a later section, but otherwise throughout the paper we shall retain the assumption that all electrons leave the cathode with zero initial velocity.

The chief cause of variation in v_n among the electrons is due to the fact that they acquire different tangential velocity components in crossing the screen and as these tangential velocities are preserved in the subsequent motion the normal velocities will thereby be affected.

Now the maximum tangential velocity component that can be acquired by an electron in crossing the screen is $v_t = \sqrt{\frac{2e}{m} \cdot V_T}$ and the minimum is zero. (We may use the same expression for V_T as before, for at the screen the potential is high, electrons move quickly and in consequence space charge densities are low. There should, therefore, be no great change in the electric field at the screen.)

It remains to decide how the tangential velocity is distributed between the limits.

In practice it is to be expected that electrons cross the screen in a fairly uniform fashion, that is to say, the current crossing a small area near the grid wire should be about the same as the current crossing the same area midway between grid wires. We may also expect that the tangential velocity acquired is in some way proportional to the distance from the mid-line between the two wires of the point at which the electron crossed the screen.

Let us consider the following laws :—

1. That the square of the tangential velocity component acquired by an electron is equally likely to be anywhere between the limits zero and $\frac{2e}{m} \cdot V_T$.

2. That the tangential velocity component acquired by an electron is equally likely to be anywhere between the limits zero and $\sqrt{\frac{2e}{m} \cdot V_T}$.

It would be difficult to verify either law directly by experiment and we shall make use of both. The chief difference between them is that in law (1) a greater number of electrons acquire large tangential velocities than in law (2).

The actual distribution arising in any particular case must to some extent be influenced by the mutual positioning of the control and screen grids. For example, in valves in which the wires of these grids are aligned (i.e., are wound with the same pitch and set so that when viewed from the cathode the wires of the control grid hide the wires of the screen), a focusing effect occurs and fewer electrons acquire large tangential velocity components than when the wires of these grids lie in a random fashion with respect to each other. The existence of space charge prevents any sharp focusing from occurring and only a small difference in velocity distribution is to be expected between the two cases.

Having decided the tangential velocity distribution of the electrons on crossing the screen grid, the normal velocity can easily be found from the fact that tangential velocity components are preserved.

Thus if v_t' is the tangential velocity acquired by a particular electron at the screen, the normal velocity v_n of that electron

* I. Langmuir. *Phys. Rev.*, 1923, Vol. 21, p. 419. Wheatcroft. "Gaseous Electrical Conductors" (Oxford University Press) or any text-book on thermionic emission.

at a plane at potential V is:

$$v_n = \sqrt{\frac{2e}{m} \cdot V - v_t'^2}$$

$$= \sqrt{\frac{2e}{m}(V - V_t')} \quad .. \quad .. \quad (9)$$

where: $\frac{1}{2}mv_t'^2 = eV_t'$

Primary Effect of Space Charge on the Knee

We have shown that the knee in the $I_a - V_a$ characteristic curve occurs at that anode voltage at which m.d. electrons are returned to the screen. We shall assume that the principle is the same when space charge is present and take as a criterion the existence of a plane at potential V_r between the screen grid and anode.

The effect of space charge is to cause a depression of the potential in the region and we shall investigate the formation of a potential minimum at potential V_r for this is the condition under which the reflection of electrons just commences.

Starting with tangential velocity distribution law (1) we shall write that the part of i composed of electrons with tangential velocity squared between nv_t^2 and $(n + dn)v_t^2$ is $i.dn$ and the space charge density may be written:

$$\rho = \int_0^1 \frac{i \,.\, dn}{\sqrt{\frac{2e}{m}(V - nV_r)}}$$

$$= 2\sqrt{\frac{m}{2e}} \cdot i \cdot \left[\frac{\sqrt{V} - \sqrt{V - V_r}}{V_r}\right] \quad .. \quad .. \quad (10)$$

To obtain the potential distribution in the region we must find a solution to Poisson's Equation:

$$\frac{d^2V}{dx^2} = 4\pi\rho \quad .. \quad .. \quad .. \quad (11)$$

(The usual form of Poissons' Equation is $\nabla^2 V = -4\pi\rho$. Throughout this paper only electronic charges are considered, and to save a repetition of negative signs we shall break the usual convention and take currents and charges as positive. V will be treated as a function of x only for we assume symmetry in the y and z directions.)

Substituting from (10) for ρ there results:

$$\frac{d^2V}{dx^2} = 4\pi \cdot \sqrt{\frac{m}{2e}} \cdot i \,.\, 2 \,.\, \left[\frac{\sqrt{V} - \sqrt{V - V_r}}{V_r}\right] \quad .. \quad .. \quad (12)$$

By integration:

$$\tfrac{1}{2} \cdot \left(\frac{dV}{dx}\right)^2 = 4\pi \cdot \sqrt{\frac{m}{2e}} \cdot i \cdot \frac{4}{3}\left[\frac{V^{3/2} - (V - V_r)^{3/2}}{V_r}\right] + C \quad .. \quad .. \quad .. \quad .. \quad (13)$$

The integration constant C may be evaluated from the condition that there is a potential minimum of value V_r, i.e. $dV/dx = 0$ when $V = V_r$.

Whence:

$$\left(\frac{dV}{dx}\right)^2 = \frac{32}{3} \cdot \pi \cdot \sqrt{\frac{m}{2e}} \cdot i \left[\frac{V^{3/2} - (V - V_r)^{3/2} - V_r^{3/2}}{V_r}\right] \quad .. \quad .. \quad .. \quad .. \quad (14)$$

Further rearrangement and integration provides:

$$\int_{V_r}^{V} \frac{dV}{\sqrt{\frac{V^{3/2} - (V - V_r)^{3/2} - V_r^{3/2}}{V_r}}} = \pm\sqrt{\frac{32}{3} \cdot \pi \cdot \sqrt{\frac{m}{2e}} \cdot i \,.\, x} \quad .. \quad .. \quad .. \quad (15)$$

---

where n is a parameter which can have any real value between 0 and 1.

Thus at a plane at potential V the part $i.dn$ of the current is composed of electrons with normal velocity components between

$$\sqrt{\frac{2e}{m} \cdot (V - nV_r)} \text{ and } \sqrt{\frac{2e}{m}[V - (n + dn)V_r]}$$

Since V_r is the lowest potential in the region there can only be forward moving electrons, where x is measured from the plane where $V = V_r$.

The indeterminate sign on the right-hand side of (15) causes no difficulty since the potential distribution is symmetrical about the potential minimum. It is convenient to choose the positive sign and treat x as a scalar quantity.

By the substitution $\gamma = V/V_r$, the integral

in (15) can be rewritten thus :—

$$V_T^{3/4}\int_1^{V/V_T}\frac{d\gamma}{\sqrt{\gamma^{3/2}-(\gamma-1)^{3/2}-1}} = V_T^{3/4}\cdot f\left(\frac{V}{V_T}\right) \quad .. \quad (16)$$

The function $f\left(\frac{V}{V_T}\right)$ has been evaluated by numerical integration and graphed in Fig. 4.

By means of (16) we may rewrite (15) in the form :

$$x = \frac{V_T^{3/4}\cdot f\left(\frac{V}{V_T}\right)}{\sqrt{\frac{32}{3}\cdot\pi\cdot\sqrt{\frac{m}{2e}}\cdot i}} \quad .. \quad .. \quad (17)$$

or if : x is in mm.

V and V_T in volts

i in mA per mm.^{2}

$$x = 0.0444\cdot\sqrt{\frac{V_T^{3/2}}{i}}\cdot f\left(\frac{V}{V_T}\right) \quad .. \quad (18)$$

Strictly this result is only applicable at a sufficient distance from the screen for the electric field to be uniform over any plane parallel to the screen, yet in view of the fact that the potential at the screen is, in all practical cases, relatively high, we need expect no peculiar space charge effects there, and we shall treat the screen as if it were a planar electron source at the potential V_g. This is not necessarily the applied voltage on the wires of the screen, but is to be regarded as the effective potential of the screen. The concept has been treated by Dow in the *Proc. I.R.E.*, 1940, and in Appendix II we repeat the relevant parts of his paper and derive the following expression for the effective potential at the screen, namely :—

$$V_g = \frac{\mu_2\, V_{a2}}{1+\mu_2+\frac{x_{2a}}{x_{12}}} \quad .. \quad .. \quad (19)$$

where μ_2 is the geometric amplification factor of a triode constructed by placing a solid cathode at the plane of the first grid of the tetrode.

By writing $V = V_g$ in (18) we obtain an expression for x_g, the distance from the screen to the potential minimum, namely :—

$$x_g = 0.0444\cdot\sqrt{\frac{V_T^{3/2}}{i}}\cdot f\left(\frac{V_g}{V_T}\right) \quad .. \quad (20)$$

Likewise the distance x_a from the potential minimum to the anode is given thus :—

$$x_a = 0.0444\sqrt{\frac{V_T^{3/2}}{i}}\cdot f\left(\frac{V_a}{V_T}\right) \quad .. \quad (21)$$

Recalling the definition given earlier that the knee anode voltage V_K is that value of the anode voltage at which the lowest potential in the region between the screen and anode is V_T, we shall proceed to solve (20) and (21) for V_K.

In the relation $x_{2a} = x_g + x_a$ we make substitutions from (20) and (21) and obtain

$$x_{2a} = 0.0444\sqrt{\frac{V_T^{3/2}}{i}}\cdot\left[f\left(\frac{V_g}{V_T}\right)+f\left(\frac{V_K}{V_T}\right)\right] \quad .. \quad .. \quad (22)$$

whence :

$$f\left(\frac{V_K}{V_T}\right) = \frac{x_{2a}}{0.0444\cdot\sqrt{\frac{V_T^{3/2}}{i}}} - f\left(\frac{V_g}{V_T}\right) \quad .. \quad .. \quad (23)$$

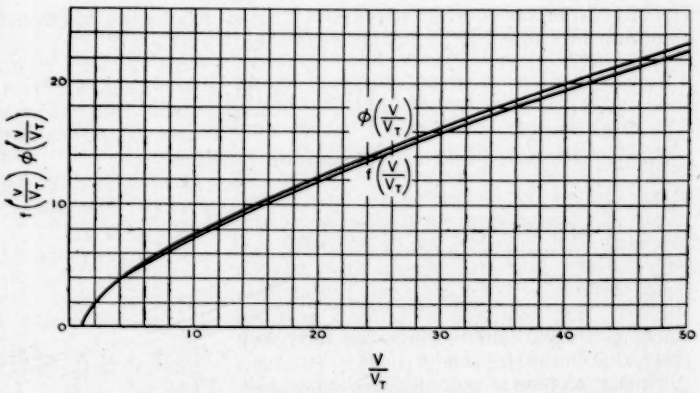


Fig. 4.

V_T and V_g can always be found by the methods already described and $f\left(\frac{V_g}{V_T}\right)$ evaluated from the graph, Fig. 4. Thus for a given value of i (and in a practical case i

is arbitrary since its value can be altered up to the limiting emissivity of the cathode by adjusting the control grid bias), the appropriate value of $f\left(\frac{V_K}{V_T}\right)$ may be obtained, and by further reference to Fig. 4 V_K/V_T and hence V_K can be had.

When the right-hand side of (23) is zero, we have $x_g = x_{2a}$, that is, the potential minimum coincides with the anode. This is an important case, for it defines the lowest value of i at which a potential minimum of amount V_T can occur.

This is contained in the equation:

$$x_{2a} = x_g = 0.0444 \cdot \sqrt{\frac{V_T^{3/2}}{i}} \cdot f\left(\frac{V_g}{V_T}\right)$$

or

$$i = \frac{(0.0444)^2 \cdot V_T^{3/2} \cdot f^2(V_g/V_T)}{(x_{2a})^2} \quad .. \quad .. \quad (24)$$

For values of i less than that given in (24) the knee anode voltage is V_T and space charge is of no consequence, but for higher values of i the knee anode voltage is given in (23).

A similar chain of reasoning may be gone through for the second tangential velocity distribution law. In this case we shall put $i.dn$ for the part of i composed of electrons with tangential velocity between nv_t and $(n + dn)v_t$.

Whence:

$$\rho = \int_0^1 \frac{i \cdot dn}{\sqrt{\frac{2e}{m}(V - n^2 V_T)}} = \sqrt{\frac{m}{2e}} \cdot \frac{i}{\sqrt{V_T}} \cdot \sin^{-1}\sqrt{\frac{V_T}{V}} \quad .. \quad .. \quad .. \quad (10a)$$

$$\frac{d^2V}{dx^2} = 4\pi\sqrt{\frac{m}{2e}} \cdot \frac{i}{\sqrt{V_T}} \cdot \sin^{-1}\sqrt{\frac{V_T}{V}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (12a)$$

$$\tfrac{1}{2} \cdot \left(\frac{dV}{dx}\right)^2 = 4\pi\sqrt{\frac{m}{2e}} \cdot i \cdot \frac{V}{\sqrt{V_T}} \cdot \left[\sin^{-1}\sqrt{\frac{V_T}{V}} + \sqrt{\frac{V_T}{V}}\sqrt{1 - \frac{V_T}{V}} - \frac{V_T}{V} \cdot \frac{\pi}{2}\right] \quad .. \quad .. \quad (14a)$$

and

$$\int_{V_T}^{V} \frac{dV}{\sqrt{\frac{V}{\sqrt{V_T}}\left(\sin^{-1}\sqrt{\frac{V_T}{V}} + \sqrt{\frac{V_T}{V}}\sqrt{1 - \frac{V_T}{V}} - \frac{V_T}{V} \cdot \frac{\pi}{2}\right)}} = \sqrt{8\pi \cdot \sqrt{\frac{m}{2e}}\, i \cdot x} \quad .. \quad (15a)$$

To preserve the form of (17) we may write:

$$x = \frac{V_T^{3/4} \cdot \phi\left(\frac{V}{V_T}\right)}{\sqrt{\frac{32}{3} \cdot \pi \cdot \sqrt{\frac{m}{2e}} \cdot i}}$$

where $\phi\left(\frac{V}{V_T}\right)$ is defined as follows:

$$\phi\left(\frac{V}{V_T}\right) = \frac{2}{\sqrt{3}} \int_1^{V/V_T} \frac{d\gamma}{\sqrt{\gamma \sin^{-1}\sqrt{\frac{1}{\gamma}} + \sqrt{\gamma - 1} - \frac{\pi}{2}}} \quad .. \quad .. \quad (16a)$$

From now on the analysis is identical, except that throughout $f\left(\frac{V}{V_T}\right)$ should be replaced by $\phi\left(\frac{V}{V_T}\right)$. In Fig. 4 a graph is drawn of $\phi\left(\frac{V}{V_T}\right)$ and it will be seen that the two functions are very similar.

To illustrate the findings so far the dotted curves in Fig. 5 were drawn showing the relations between the calculated knee anode voltage and current for the two laws. Such curves will be referred to as "knee loci."

TABLE 2

$x_{01} = 0.340$;	$x_{12} = 0.610$;	$x_{2a} = 3.342$
$p_1 = 0.65$;	$p_2 = 0.65$;	$l = 14.5$
$d_1 = 0.080$;	$d_2 = 0.080$;	$b = 2.15$

$V_T = 12.15$ volts; $V_{g2} = 150$ volts; $A = 80$ sq. mm.

The dimensions used were those of an actual valve (*see* Table 2). A difficulty occurs in relating i the current density with I the

total current passed, in view of the fact that the cathode is narrow and there must be appreciable spreading in the electron beam. In the above curves we have taken i as the ratio $\frac{I}{A}$ where A is the area of the flat emitting surfaces of the cathode. There is no doubt that such an assumption errs in giving i too high a value, but the question of beam spread will be considered in a later section.

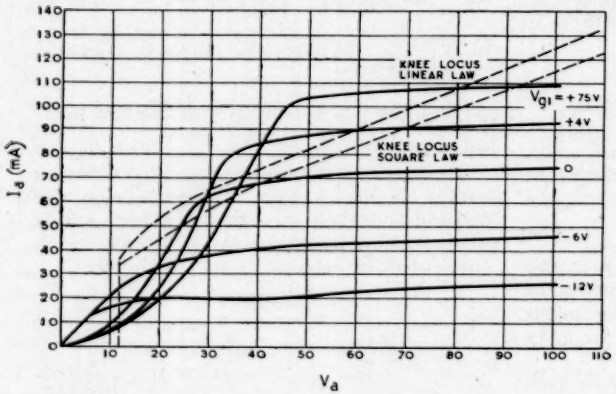


Fig. 5.—*Calculated "knee loci" for the "square" and "linear" tangential velocity distribution laws superimposed on an actual family of $I_a - V_a$ characteristic curves. (For valve dimensions see Table 2). The calculations do not take beam spread into account and it can be seen that the slopes of the loci are too small.*

The heavy lines in Fig. 5 show the observed $I_a - V_a$ characteristics.

The Effect of the Temperature Velocity Distribution of Electrons on Space Charge Density

In the previous section we derived an expression for the space charge density at any plane of potential V, in the screen anode region for the case that a potential minimum of value V_T exists.

We shall now carry out a similar derivation but without the assumption that electrons leave the cathode with zero energy.

It is shown in works on thermionic emission that the part di of the current per unit area (i) due to electrons with initial forward velocity between u and $(u + du)$ is approximately:

$$di = i \,.\, \frac{m}{KT} \,.\, \exp.\left(-\frac{mu^2}{2KT}\right) \,.\, u \,.\, du$$

where m is the mass of an electron,
K is Boltzmann's Constant and
T is the absolute temperature at the cathode.

Let us assume that the electrons of this elementary group acquire tangential velocity components on crossing the screen in accordance with Tangential Velocity Distribution Law I, then it follows that at a plane at potential V the part $di \,.\, dn$ of the current is composed of electrons with normal velocity between:

$$\sqrt{\frac{2e}{m} \,.\, (V - nV_T) + u^2}$$

and $$\sqrt{\frac{2e}{m} \,.\, (V - (n + dn)V_T) + u^2}$$

Let: $\frac{1}{2} \,.\, mu^2 = eU$

then the space charge density can be expressed by the double integral:

$$\rho = \int_0^\infty dU \int_0^1 i \,.\, \frac{e}{KT} \,.\, \exp.\left(-\frac{eU}{KT}\right) \,.\, \frac{dn}{\sqrt{\frac{2e}{m}(U + V - nV_T)}} \qquad .. \quad .. \quad .. \quad (26)$$

which, by integration and rearrangement, gives:

$$\rho = 2i \,.\, \sqrt{\frac{m}{2e}} \,.\, \left[\frac{\sqrt{V} - \sqrt{V - V_T}}{V_T}\right] - \frac{i\sqrt{\pi \,.\, m \,.\, KT}}{eV_T\sqrt{2}} \,.\, \left[E\left(\frac{e(V - V_T)}{KT}\right) - E\left(\frac{eV}{KT}\right)\right] \qquad (27)$$

where $E(x) = (\exp. x)\,(1 - erf\sqrt{x})$

It will be noted that the first term in this expression is identical with that derived for ρ in equation (10) and so the second term gives the reduction in charge density due to the temperature distribution.

It is convenient to write $\frac{V}{V_T} = \gamma$ and $\frac{eV_T}{KT} = \beta$ where γ and β are both dimensionless.

Then:

$$\rho = i \cdot \sqrt{\frac{2m}{eV_T}} \cdot \left[\sqrt{\gamma} - \sqrt{\gamma - 1} - \tfrac{1}{2} \cdot \sqrt{\frac{\pi}{\beta}} \cdot \left\{ E[\beta(\gamma - 1)] - E[\beta\gamma] \right\} \right] \quad .. \quad .. \quad (28)$$

and the fraction by which the charge density is decreased may be written:

$$F = \frac{\tfrac{1}{2} \cdot \sqrt{\frac{\pi}{\beta}} \cdot \{E[\beta(\gamma - 1] - E[\beta\gamma]\}}{\sqrt{\gamma} - \sqrt{\gamma - 1}} \quad .. \quad .. \quad (29)$$

Since, for large values of x, $erf\, x \to 1 - \frac{e^{-x^2}}{\sqrt{\pi} \cdot x}$, it follows that for large values of γ, F tends to $\frac{1}{2\beta} \cdot \frac{1}{\sqrt{\gamma(\gamma - 1)}}$ which very soon becomes negligible.

When γ is near to unity the value of F depends very much on β and tends to unity as $\beta \to 0$. This limit is of no practical importance, for in all cases the value of β is of the order of 100.

It is interesting to evaluate F for a set of values of γ for the valve described in the previous section. This valve may be regarded as typical, and we have chosen $T = 786°$ C, which is well within the normal temperature range employed in valves with oxide coated cathodes.

It follows from the relation $\beta = \frac{eV_T}{KT}$ that β has the value of $\frac{4}{3} \times 10^2$, and the following table was prepared from expression (29).

$\gamma = V/V_T$	F
1.00	0.0730
1.01	0.0273
1.10	0.0107
2.00	0.00263
11.00	0.000357

It is significant that the greatest difference in space charge density is less than 8 per cent. and occurs at the potential minimum. At a potential of 1.1 of the potential minimum the difference has dropped to 1 per cent. and becomes vanishingly small further away.

This in itself is enough to justify the neglect of the emission velocity distribution in estimating the potential in the field, but by substituting expression (27) for ρ in (11) and carrying out integrations and rearrangements as in the previous section, it can be shown that the relation between potential and distance is given in the equation:

$$\int^{V/V_T} \frac{d\gamma}{\sqrt{[\gamma^{3/2} - (\gamma - 1)^{3/2} - 1] + \tfrac{3}{4} \cdot \sqrt{\pi} \cdot \left(\frac{1}{\beta}\right)^{3/2} \left\{ E(\beta\gamma) - E(\beta) - E[(\gamma - 1)\beta] + \frac{2}{\sqrt{\pi}} \left(\sqrt{\gamma\beta} - \sqrt{\beta} - \sqrt{(\gamma - 1)\beta} \right) - 1 \right\}}} = \sqrt{\frac{32}{3} \cdot \sqrt{\frac{m}{2e}} \cdot \pi \cdot \frac{i}{V_T^{3/4}} \cdot x} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (30)$$

and the integral in (30) differs by a quite insignificant amount from $f\left(\frac{V}{V_T}\right)$.

APPENDIX 1

An expression for v_t and hence V_T may be found by making use of a method given by Spangenberg*, by which he calculates the transverse displacement of the m.d. electron in its flight from cathode to grid. In fact, Spangenberg obtains an expression for the transverse velocity component at the grid as a step toward his result.

By means which need not be described here he arrives at the following expression for the transverse acceleration of the m.d. electron, namely:—

$$\frac{d^2y}{dt^2} = \frac{h_2}{(t^2 - r_1)(t^2 - r_2)} \quad .. \quad .. \quad .. \quad (1.1)$$

Where:

$r_1 = t_0^2 (1 + j \cdot r)$
$r_2 = t_0^2 (1 - j \cdot r)$
$r = d/2x_{01}$
t_0 = the time of flight to the grid
$h_2 = -4 \cdot \frac{m}{e} \cdot \frac{\lambda d}{F_t^2}$
$j = \sqrt{-1}$

* K. Spangenberg. *Proc. I.R.E.*, May 1940, Vol. 28, p. 226.

F_f = the forward accelerating force on the electron (assumed constant throughout)

$$\lambda = \frac{p\mu[(x_{01}+x_{12})V_g - x_{01}V_a]}{4\pi x_{12}(x_{01}+x_{12}+\mu x_{01})} \quad (1.2)$$ { this is the charge induced per unit length of a grid wire.

By integrating (1.1) with respect to t we obtain :

$$\frac{dy}{dt} = \frac{k_2}{r_1 - r_2}\left[\frac{2}{\sqrt{r_1}} \cdot ln\left(\frac{\sqrt{r_1}-t}{\sqrt{r_1}+t}\right) - \frac{2}{\sqrt{r_2}} \cdot ln\left(\frac{\sqrt{r_2}-t}{\sqrt{r_2}+t}\right)\right] + C \quad .. \quad (1.3)$$

This expression is equivalent to equation (37) in Spangenberg's paper.

The integration constant may be specified from the condition that the electron leaves the cathode with no initial velocity.

i.e. $\frac{dy}{dt} = 0$ when $t = 0$ and hence $C = 0$.

By writing $t = t_0$ in (1.3) we obtain the tangential velocity component at the grid of a m.d. electron. The resulting expression must now be simplified. This is most readily done by expansion of the various terms, retaining only the lowest powers of r, whence :

$$\left(\frac{dy}{dt}\right)_{t=t_0} = \frac{k_2}{2r \cdot t_0^3}\left[\frac{\pi}{2} - \frac{r}{2} \cdot ln\frac{r}{4}\right] = \frac{2m \cdot \lambda \cdot \pi \cdot x_{01}}{F_f^2 \cdot t_0^3}\left[1 - \frac{r}{\pi} \cdot ln\frac{r}{4}\right] \quad .. \quad (1.4)$$

We have further that :

$$\tfrac{1}{2} \cdot F_f \cdot t_0^2 = x_{01}$$

and : $$v = F_f \cdot t_0$$

where v is the forward velocity at the grid. Since in all practical cases the tangential velocity is small compared with the forward velocity component, no great error is introduced by writing $v = \sqrt{\frac{2e \cdot V_g}{m}}$

Whence :

$$\left(\frac{dy}{dt}\right)_{t=t_0} = -\sqrt{\frac{e}{2mV_g}} \cdot \pi \cdot \lambda \cdot \left[1 - \frac{r}{\pi} \cdot ln\frac{r}{4}\right] \quad .. \quad .. \quad (1.5)$$

We may take v_t to be twice this value in that the tangential force on the electron is only appreciable near the grid, and hence the tangential velocity acquired before and after crossing must be about the same.

Thus : $$v_t = \sqrt{\frac{2e}{mV_g}} \cdot \pi \cdot \lambda \cdot \left[1 - \frac{r}{\pi} \cdot ln\frac{r}{4}\right] \quad .. \quad (1.6)$$

and hence :

$$V_T = \tfrac{1}{2} \cdot \frac{m}{e} \cdot v_t^2 = \frac{\left\{\pi \cdot \lambda \cdot \left[1 - \frac{r}{\pi} \cdot ln\frac{r}{4}\right]\right\}^2}{V_g} \quad .. \quad .. \quad (1.7)$$

It will be noted that the expression for V_T (1.7) contains both V_a and V_g, and so for the critical case when $V_a = V_T$ (1.7) is a quadratic equation in V_T. It is convenient to make a further approximation and omit the term involving V_a in the expression for λ (1.2). This is permissible when V_a is small compared with V_g. It follows, then, that V_T is proportional to V_g (*see* equation (7) in the text).

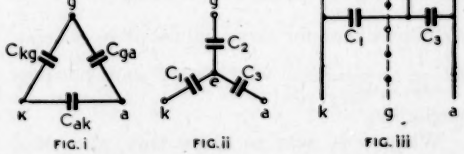
APPENDIX II

Analysis of the Electric Field

The electric field in the planar triode may be determined with sufficient accuracy by means of a conformal transformation of the type $W = \text{exp. } z$ (*see* for example Vodges and Elder* or Dow†) and the method could also be used for a valve with more than one grid, but it becomes cumbersome and a satisfactory degree of accuracy can only be obtained at the expense of a great amount of labour. In the paper referred to in the text Dow obtained a valuable simplification of the multigrid valve problem by treating the mutual inter-electrode capacitances.

To understand his method consider first the planar triode. It is usual to represent the capacitance relationship between the three electrodes by the "delta" network in Fig. i. This is not the most convenient scheme for calculation and he transposes to the equivalent "star" network of Fig. ii. Each element in this latter network can be expressed in terms of the three elements of the former and *vice versa*.

From a knowledge of the electric field in the triode, it is possible to evaluate each of the elements and when this is done the fact emerges that C_1 and C_3 are to a close approximation the capacitances which would exist between the cathode and a plate in the plane of the grid, and between this plate and the anode respectively. The nearness of the approximation depends on the form and position of the grid, and the method breaks down for a grid with thick wire or very open pitch. Safe limits are : $\frac{d}{p} > \frac{1}{6}$ and the pitch should not exceed by much the spacing to the nearer electrode. To be more explicit, the method requires that the field irregularities near the wires of the grid have evened out before the cathode and anode so that at these latter two planes it would appear that the grid is planar, and we can therefore refer to a fictitious electrode at the plane of the grid.



For a given set of applied voltages the potential of the fictitious electrode is the potential of the point (e) in Fig. ii, and this shows how we can interpret the capacitance C_2, namely, as the capacitance between the fictitious electrode and the actual wires of the grid, *see* Fig. iii. It is impossible to form a physical picture of the capacitance between a fictitious electrode and real wires in its plane, but this is no objection to making use of the device. The potential at (e) will be

* Vodges and Elder. *Phys. Rev.*, Dec. 1924, Vol. 24, p. 683.

† W. G. Dow. "Fundamentals of Engineering Electronics." (Chapman and Hall.)

called the " Effective Potential " of the grid, and this is a most useful concept for it is often desirable to treat a grid as if it were a uniform potential plane.

The value of C_2 may be obtained by noting that the geometric amplification factor of the triode is $\frac{C_{kg}}{C_{ak}} = \frac{C_2}{C_3}$ and hence $C_2 = \mu C_3$ .. .. (2.1)

where μ is given by the formula : $\mu = \frac{2\pi x_{1a}}{p \; ln \coth \frac{\pi d}{p}}$ .. .. (2.2)

Thus taken per unit area,

$$C_1 = \frac{1}{4\pi . x_{01}}; \quad C_3 = \frac{1}{4\pi . x_{1a}}; \quad C_2 = \frac{1}{2 \; ln \coth \frac{\pi d}{p}}$$

Consider now the multigrid valve. If it can be assumed that between each grid there is a region in which the electric field is uniform, then it follows that we may replace any grid by a plane at some intermediate potential without disturbing the field in the neighbourhood of the adjacent electrodes, and the star network can be extended as in Fig. iv.

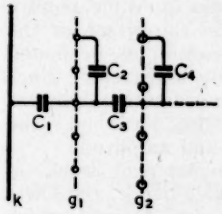


FIG. iv

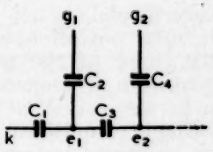


FIG. v

In effect, so far as concerns the calculation of electric field, the valve has been reduced to a set of component triodes with fictitious electrodes at the grids acting in turn as " cathodes " and " anodes." We shall take μ_1, μ_2, μ_3, etc., to be the amplification factors of these triodes, and their values may be determined by using the relevant dimensions in equation (2.2).

For example :

$$\mu_2 = \frac{2\pi x_{23}}{p_3 . \; ln \coth \frac{\pi d_3}{p_3}}$$

To complete the field analysis all that is necessary is a knowledge of the potentials of the fictitious electrodes in the grid planes. These may be obtained very simply from the capacitance network, Fig. v

The potentials at e_1, e_2, e_3, etc., in Fig. v are the potentials required and they are given in the equations :

$$\begin{aligned} &(Vk - Ve_1)C_1 + (Vg_1 - Ve_1)C_2 + (Ve_2 - Ve_1)C_3 = 0 \\ &(Ve_1 - Ve_2)C_3 + (Vg_2 - Ve_2)C_4 + (Ve_3 - Ve_2)C_5 = 0 \\ &. \; . \; . \; .

Calibrated
RESPONSE CURVE TRACER*

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SUMMARY.—An apparatus is described which greatly facilitates the alignment of R.F. and I.F. band-pass amplifiers. With its aid the response curve of the amplifier to be aligned is continuously traced on the screen of a cathode-ray tube in conjunction with a co-ordinate system of frequency and amplitude derived from a standard signal generator.

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(1) Introduction
(2) Principles of Operation
  (2.1) The Amplitude Calibrator
  (2.2) The Frequency Calibrator
(3) Detailed Circuit
  (3.1) The A unit (Frequency Sweep Generator)
  (3.2) The B unit (Calibrator)
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  (3.3) The C unit (Output Amplifier)
(4) Conclusions

1. Introduction

THE difficulties of the correct alignment of R.F. and I.F. band-pass amplifiers are generally appreciated for the amplifier has to be so adjusted that its response curve satisfies certain prescribed requirements as regards shape and location in the frequency spectrum. The difficulties in this process of alignment arise from the fact that on the one hand a multitude of variable quantities, such as mutual and self inductors, capacitors and resistors have to be adjusted to their correct value, each adjustment affecting the whole of the response curve in some way, while on the other hand the result of these adjustments is not directly visible and measurable. True enough, with the aid of a signal generator and an output meter the response curve for a particular setting of all variables can be measured point by point and then plotted, but this is an intolerably lengthy process. To relieve the situation frequency-sweep generators are generally used instead of the steady-signal generator, and the *Y*-plates of a cathode-ray tube in place of the output meter. Thus it is possible in conjunction with a suitable time base applied to the *X*-plates to obtain a visible picture of the response curve on the screen of the C.R.O. However, this method, although very helpful, is not fully satisfactory since it does not afford a co-ordination between the shape of the response curve and the quantities of frequency and amplitude.

In the course of development work on variable bandwidth wide-band amplifiers an auxiliary apparatus was evolved which overcomes all the aforementioned difficulties. It permits the continuous observation on the screen of a C.R.O. of the response curve of the amplifier under test together with a co-ordinate system indicating frequency and amplitude derived from a standard signal generator. Before going into the explanation of the apparatus it

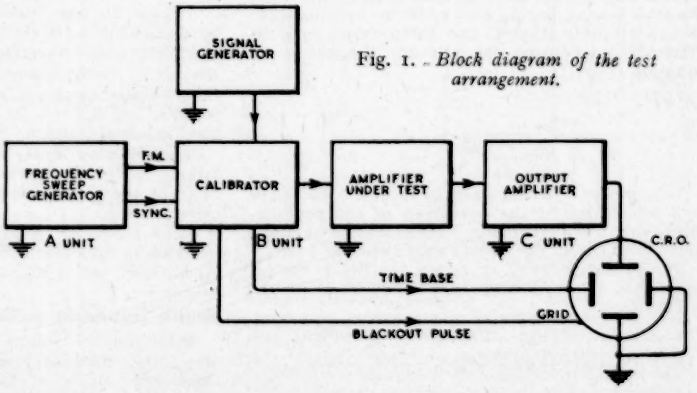


Fig. 1. — *Block diagram of the test arrangement.*

* MS. accepted by the Editor, November, 1944.

seems desirable first to outline how it is used and what picture it produces.

Fig. 1 shows the block diagram of the test arrangement, the first unit A, contains a frequency sweep generator producing a carrier, the frequency of which oscillates between the values within which the amplifier is to be tested. Since pass bands up to 600 kc/s around a carrier of 5 Mc/s were envisaged, a frequency sweep of 1 Mc/s seemed to afford sufficient information about the filter curve. Such wideband sweeps are most conveniently accomplished by an ordinary LC oscillator with a motor driven tuning capacitor. A limiter stage takes care of the necessary constant R.F. output at all frequencies, and a small alternator coupled to the motor produces a sinusoidal synchronising frequency. These

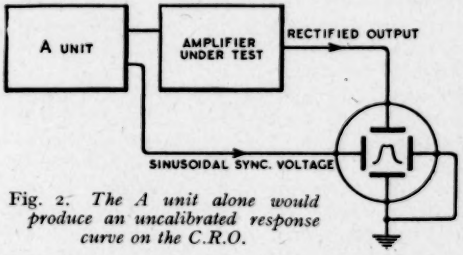


Fig. 2. *The A unit alone would produce an uncalibrated response curve on the C.R.O.*

three elements: F.M. oscillator, limiter and synchronising alternator make up the first unit. If unit A were connected to the amplifier under test in the manner indicated in Fig. 2, the picture on the screen of the cathode-ray tube would merely indicate the shape of the filter curve. In order to provide the calibration a second unit, B, the calibrator, has to be inserted between the A unit and the amplifier under test. If the standard signal generator is connected to unit B (*see* Fig. 1), (the presence of the C unit can be neglected for the time being), the calibration will show on the screen in the following manner: The trace of the response curve will have a small gap which indicates the frequency to which the signal generator is tuned (*see* Fig. 3). Consequently tuning the signal generator through the frequency range considered shifts the gap along the trace of the response curve. Thus the first quantity, viz., the frequency, can be located on the diagram on the screen. The second quantity, the amplitude is indicated by a horizontal level line which can be shifted up and down by operating the attenuator of the signal generator. In this way the decibel difference between any two points of the response curve can be read off the attenuator scale of the signal gen-

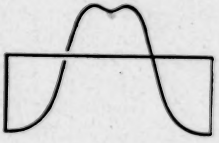


Fig. 3. *By the insertion of the calibrator according to Fig. 1 this type of picture is produced on the C.R.O. The gap in the trace indicates the frequency, the level line the amplitude to which the standard signal generator is set.*

erator. Therefore any desired point of the filter curve can immediately be located with regard to frequency and amplitude.

2. Principles of Operation

(2.1) *The Amplitude Calibrator.* — This works on the following principles (*see* Fig. 4). By means of a throw-over switch the amplifier under test is fed alternatively with the frequency-modulated signal from unit A and the steady signal from the signal generator. The desired result is then achieved by feeding the rectified output to the *Y*-plates and arranging a time base for the *X*-plates such that the response to a single frequency sweep from minimum to maximum frequency is recorded by the forward stroke in the *X*-direction, thus tracing the

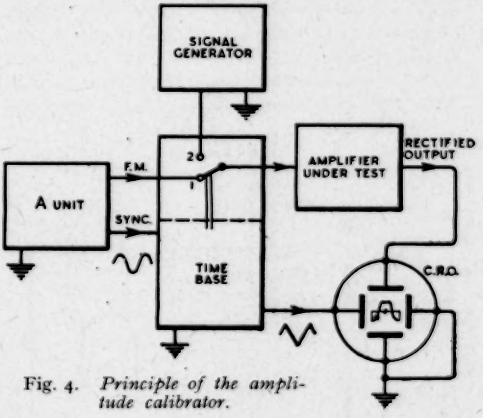


Fig. 4. *Principle of the amplitude calibrator.*

filter curve and the response to the steady-signal generator by the backward stroke tracing the level line. This action requires that the time base delivers a triangular voltage wave in such a way that the occurrence of every apex of the triangular wave coincides with a throw-over action of the

switch. Also care must be taken that the frequency-modulated signal reaching the amplifier under test when the switch is in position 1 really sweeps between minimum and maximum frequency. This therefore calls for a correct phase adjustment between the rotating condenser and the synchronising voltage.

(2.2) *The Frequency Calibrator.*—The gap in the response trace indicating the coincidence of the momentary frequency of the sweep with the frequency of the signal generator is produced by a negative black-out pulse applied to the grid of the cathode-ray tube. This negative pulse is generated by a multi-vibrator, which in turn is synchronised from the audio beat resulting from the interaction of the steady and variable frequency in a mixing valve. Fig. 5 indicates this principle. As the frequency of the A unit approaches the steady frequency of the signal generator an audible beat voltage is produced across the anode load resistor R_5 of the mixer which, due to the relatively heavy shunt capacitor C_6, increases in amplitude as the audio pitch is reduced. After the sweep has passed the frequency of the signal generator the pitch of the beat grows higher and its amplitude decreases again (Fig. 9h). If this beat wave is rectified it emerges from the filter circuit in the shape of a little hump having its maximum amplitude around zero beat, just where the two radio frequencies coincided (Fig. 9i). It is this hump which triggers the multi-vibrator. It is evident that this method of frequency calibration is only applicable for wide frequency sweeps if

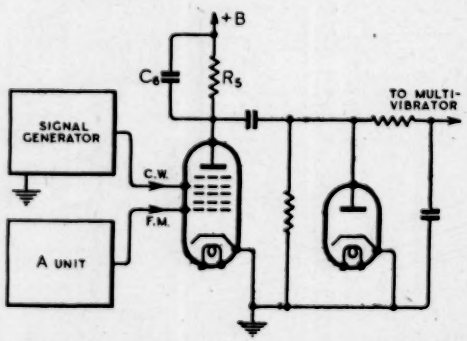


Fig. 5. *Principle of the frequency calibrator.*

reasonable accuracy is desired, for, since the synchronising hump is a graph of the audio response of the mixer anode load, the synchronisation takes place plus or minus a few thousand cycles around the accurate spot of high frequency coincidence. Consequently the total frequency sweep must be quite a considerable multiple of those few thousand cycles. (*See* Appendix.)

3. Detailed Circuit

(3.1) *The A Unit.*—The essence of this unit is the motor-driven rotating capacitor which is of the balanced series-gap type. It is indicated schematically in Fig. 6. Two important points can be seen at once, viz., the rotor is perfectly symmetrical and it is insulated; the former offering the advantage of vibration free running, and the latter avoiding contact troubles, which inevitably would occur with wiping contacts. The capacitor is driven by an ordinary fractional horse-power D.C. series motor, the speed of which can be controlled by a variable series resistance. In the experimental model the variable speed was found to be useful in detecting, by means of stroboscopic effects, possible 50 c/s pick-ups in the rest of the apparatus. It also helps in identifying distortion of the response curve due to unfavourably chosen rectifier time constants in the amplifier under test as well as F.M. transients in extremely sharply tuned circuits.

Coupled with the motor is the alternator consisting of a permanent-magnet yoke on which is wound a centre tapped pick-up coil. The armature is formed by a suitably shaped piece of soft iron, so that for one revolution of the motor two cycles of synchronising voltage are produced, corresponding also to two cycles of capacitance variations of the butterfly-type rotating capacitor. The output of the yoke coil is fed to a simple RC circuit, which permits a shift of the phase of the synchronising output voltage by nearly 180 degrees with respect to the phase of the capacitance variation. This arrangement facilitates the correlation of the throw-over action of the switch of the amplitude calibrator with the maximum excursions of the frequency sweep.

The rotating condenser C_1 forms part of the capacitance of the tuned circuit excited by an electron coupled oscillator valve V_1. The tuning capacitor C_2 can be manually adjusted and so affords the possibility of shifting the sweep within the frequency spectrum. This, incidentally, will show up as a horizontal shifting of the filter curve across the screen of the C.R.O.

The sinusoidal output of the oscillatory circuit is fed to the limiter stage V_2, which is of conventional structure utilising the saturation principle. Only a few hundred ohms form its anode load, so that shunt capacitances cannot affect the output amplitude at different frequencies. The F.M. output is led through a coaxial cable to the unit B.

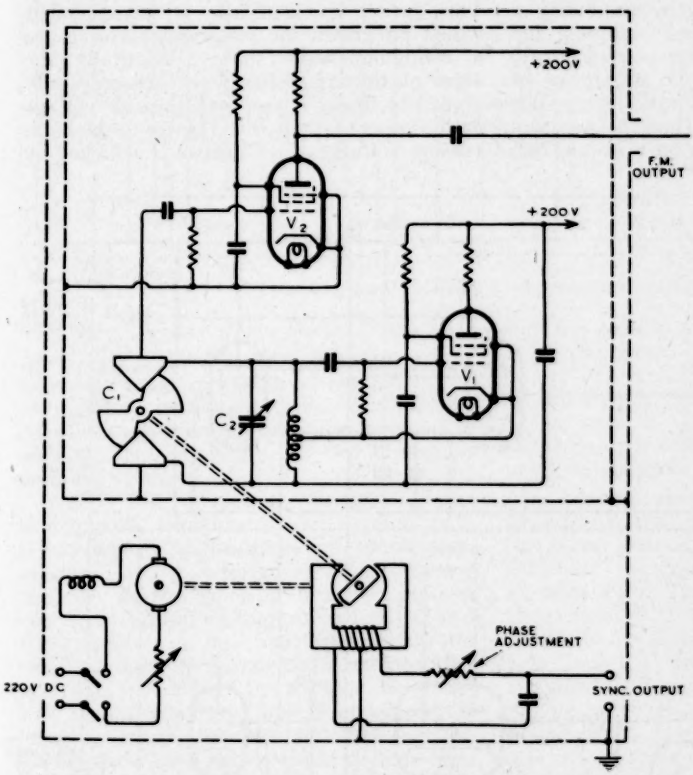


Fig 6. *The A unit containing rotating capacitor, oscillator, limiter and synchronising alternator.*

(3.2) *The B Unit*

(3.2.1) *The Amplitude Calibrator.*—The essential part of the amplitude calibrator is the throw-over switch.

A mechanical switch was considered impracticable. An electronic solution, however, proved to be extremely reliable. In essence the electronic throw-over switch consists of two H.F. pentodes V_3 and V_4 operating upon the same anode load (*see* Fig. 7). The control grid of one valve, V_3, continuously carries the F.M. signal, the control grid of the other valve, V_4, the constant frequency signal. In order to ensure that both signals are never amplified simultaneously the suppressor grid of one valve is always negative at any time so as to make that valve completely non-conductive. By applying to the respective suppressor grids two rectangular voltage waves in phase opposition these two valves become alternatively conductive, amplifying the F.M. signal for one half period and the constant frequency signal for the other half period, thus functioning as a throw-over switch.

The rectangular switching voltages are derived from the sinusoidal synchronising voltage delivered from the A unit. This voltage, of the order of a hundred volts peak, is clipped by the double diode V_5 to a nearly rectangular voltage by cutting off both the positive and negative sine hump to plus and minus 3 volts. This resulting small, nearly rectangular, actually trapezoidal, voltage is amplified in the first half of the double triode V_6 and again amplified in the second half of V_6 so that two rectangular voltages of the order of 150 V peak to peak appear in phase opposition to one another at the respective anode loads of the double triode V_6. However, the switching voltages ultimately fed to the suppressors of V_3 and V_4 have to satisfy another condition besides being almost rectangular and in anti-phase. The pentode that happens to be conducting at a particular instant must have a voltage at its suppressor grid which is kept scrupulously constant during the conducting period, otherwise the amplified radio frequencies would appear in the output as modulated by the suppressor grid voltage variations, a certainly undesirable feature. To achieve this constancy of the switching voltages

during the conducting period the low impedance between grid and cathode of a valve under grid current conditions is utilised. Take for example the instant when the grid G_1 of the first triode of V_6 is negative; then its anode will be positive and will tend to pull the grid G_2 of the second triode of V_6 also to positive values. The grid current in G_2, however, will prevent its voltage from reaching values substantially greater than the cathode potential zero by producing a voltage drop across R_1 and charging the coupling capacitor C_3. The voltage at G_2 and consequently also at the suppressor of V_3 will, therefore, be substantially zero for the switching-on period. That the negative portion of the switching voltage is sloping due to the discharge of the capacitor C_3 is of no importance since at any rate this negative voltage is larger than just necessary to put V_3 out of action. Similar arguments hold good for the other phase of the switching voltage which utilises the grid cathode portion of V_7.

The triangular time-base voltage is generated by charging a capacitor C_5 through a resistor R_3 and discharging it through a valve V_7 in series with another resistor R_4, which is effected by applying one of the aforementioned switching voltages to V_7. This circuit is essentially an arrangement which integrates the rectangular voltage to a triangular wave shape. Naturally the sides of the triangular wave are only substantially linear if the peak-to-peak voltage of the wave is small with respect to the high-tension voltage, which in turn is achieved by making the time constants C_5R_3 and C_5R_4 long compared with the duration of the sweep period. It was found, however, that a

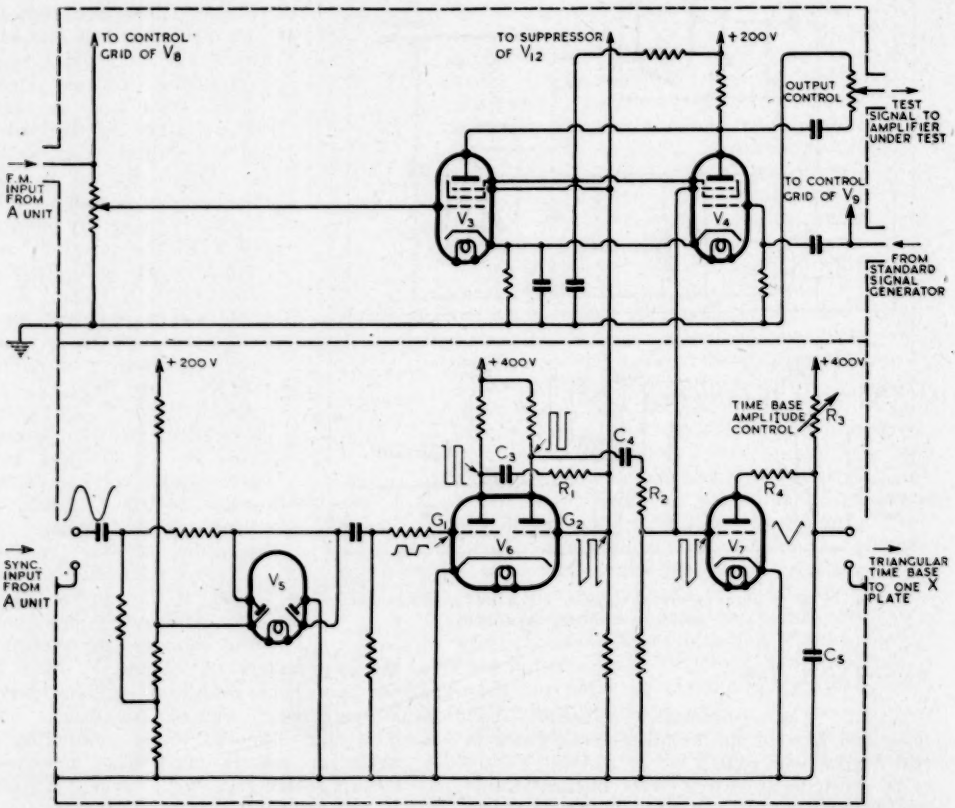


Fig. 7. *Detailed circuit of the amplitude calibrator.*

certain amount of non-linearity is desirable since it can serve to compensate in first approximation for a non-linearity of the

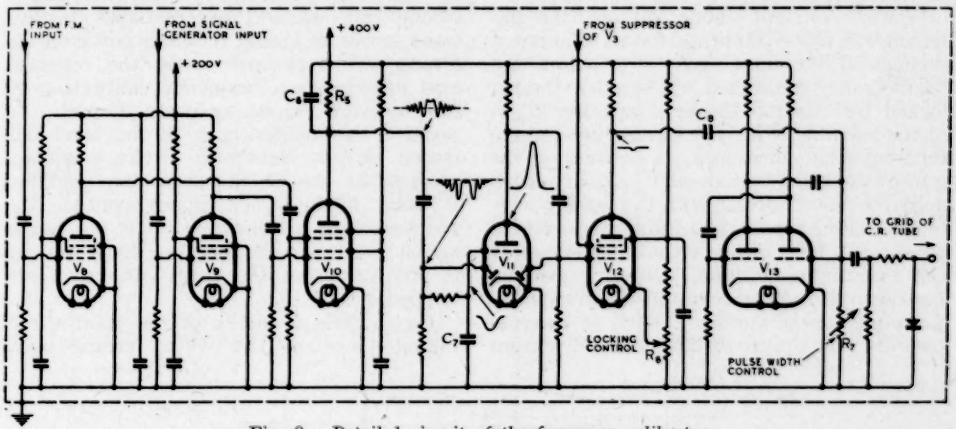


Fig. 8. *Detailed circuit of the frequency calibrator.*

frequency sweep which follows the law $1/\sqrt{C_1 + C_2}$ (*see* Fig. 6). As a result the frequency scale appearing on the screen can be made approximately linear. The variable resistor R_3 incidentally provides a means of altering the amplitude of the triangular scanning voltage.

(3.2.2) *The Frequency Calibrator.*—The principle as explained under Section (2.2) is not directly applicable in the simple form indicated in Fig. 5 for two reasons. Firstly the two control grids of a mixer are not entirely free from mutual interaction, so that there appears on one control grid a certain small amount of the signal from the other grid, and *vice versa*. If, therefore, the mixer were fed directly from the F.M. and the signal generator input, the clean action of the electronic throw-over switch would be somewhat marred, since in each position both signals would be present in a certain proportion to each other. Hence it was found necessary to insert the buffer valves V_8 and V_9 (*see* Fig. 8) between the two R.F. inputs and the mixer which unidirectionally separate the mixer from the two R.F. inputs. The second reason for an elaboration of the bare principle of Fig. 5 is that frequency calibration should operate over a range of attenuator settings of the signal generator embracing some 20 to 30 db. which entails that the voltage hump synchronising the multivibrator also varies in amplitude by that amount and yet, the locking conditions should remain the same. An automatic volume control scheme was ruled out since it would involve a reserve of R.F. amplification not readily available from an untuned R.F. amplifier. Therefore a synchronising hump of varying amplitude had to be accepted, and the locking had to be effected in such a way that just the very tip of the hump is used for synchronisation, thus being independent of its amplitude.

As already mentioned, the F.M. output from the A unit and the steady R.F. from the signal generator are amplified aperiodically in the respective buffer pentodes V_8 and V_9. The anode loads are only 1000 ohms each, in order to provide a substantially constant gain of about 7, for high slope R.F. pentodes are used. The two amplified R.F. signals are then fed to the mixing valve V_{10}, the load of which, consisting of R_5 (250 000Ω) and C_6 (1000 pF), was chosen so as to make sure that only the beat and actually only its lower pitched tones are sufficiently amplified. The first diode of V_{11} rectifies this beat, and the filtered hump with negative polarity appears across the capacitor C_7 and is amplified and inverted by the triode of V_{11}. The hump voltage at the anode has now a positive peak, and the second diode of V_{11} provides a means of adjusting this peak automatically to earth potential whatever the hump amplitude may be, for the anode of this second diode can never be more positive than earth. This referred peak is then fed directly to the grid of the locking pentode V_{12}, the cathode voltage of which can be altered by the

locking control R_6. If it is adjusted to a value a little smaller than the cut-off grid voltage just the tip of the hump will be amplified resulting in a negative pip in the otherwise constant anode voltage, the pip having the same amplitude for all attenuator settings of the signal generator within the decibel range considered. The multi-vibrator locked by this pip through capacitor C_8 is of the asymmetrical type having two largely different time constants. It delivers on the grid of the second triode of V_{13} a very sharp negative pulse starting with the leading edge of the locking pip. Its duration can be varied by R_7. To level out a certain unevenness in the essentially constant voltage prevailing between the occurrence of the negative pulses a simple metal rectifier circuit is inserted between the multi-vibrator and the output terminal connecting to the grid of the cathode-ray tube. The action of this rectifier is the same as that of the grid-cathode portion of V_7 in Fig. 7 discussed in Section (3.2.1).

It is obvious that a beat is produced twice during one cycle of operation, namely, once when the signal of the A unit sweeps towards its maximum frequency excursion and a second time when it sweeps back, the forward stroke recording the filter curve on the screen, the backward stroke the constant load line, hence a frequency calibration on the forward stroke only is desired. To avoid a meaningless gap in the level line traced by the backward stroke, the suppressors of one of the switching pentodes V_3 and of the synchronising pentode V_{12} are connected so that also V_{12} is put out of action for this half period. Hence no pip is produced, and the multi-vibrator is not tripped.

Fig. 9 gives a survey of the main effects taking place in the whole arrangement.

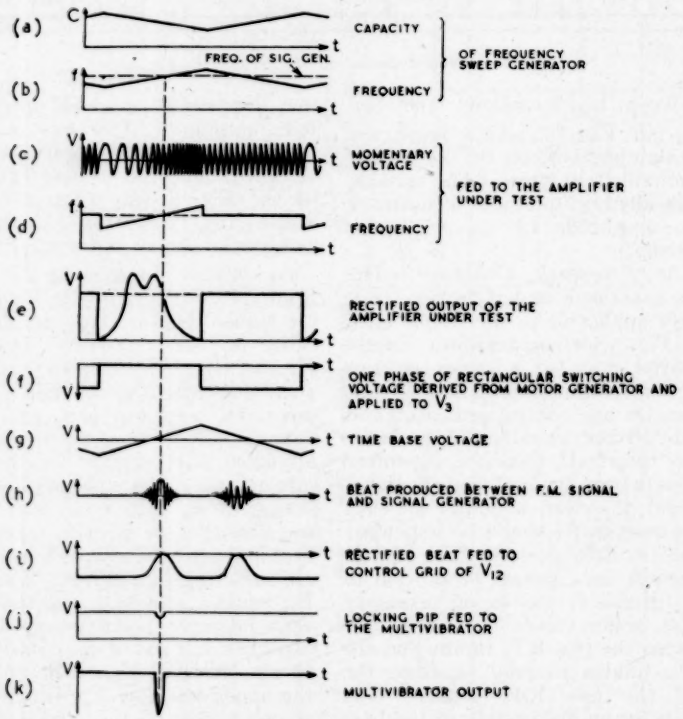


Fig. 9. *Some of the salient phenomena taking place in the total circuit plotted against the same time scale.*

The quantities are plotted against a common time scale so that the simultaneous occurrences of the individual effects can easily be followed up.

(3.3) *The C Unit.*—Recalling that the

object of the apparatus described is to facilitate the alignment of high-frequency multi-stage bandpass amplifiers it will be realised that it is not quite obvious in which way the response of the amplifier under test should be tapped off its circuit without disturbing the latter by introducing impedances alien to the amplifier under ordinary working conditions. It is easy enough to feed the amplifier with the test radio frequencies for the B unit has a low impedance output approximately matching the impedance of the coaxial feeder line, and a low impedance voltage source is inherently an easy proposition. To tap the response voltage off some amplifier filter, however, demands anything short of an infinite voltmeter impedance if the circuit is to remain undisturbed. Needless to say that especially at high frequencies such high impedances are impracticable.

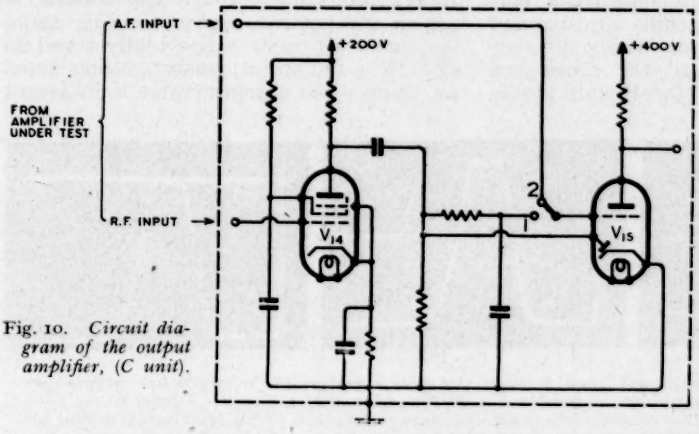


Fig. 10. *Circuit diagram of the output amplifier, (C unit).*

The outlined problem presents itself in two possible forms. One can either tap the R.F. response voltage off a low impedance point in the amplifier, and rectify and audio amplify in the separate C unit of Fig. 1, or one can make use of the rectifier usually comprised in the R.F. amplifier under test, tap the rectified voltage and just audio amplify in the C unit. Which method is to be employed depends on the electrical and mechanical construction of the amplifier to be aligned.

Before making suggestions about the alignment proper the C unit will briefly be described (*see* Fig. 10). It consists of an aperiodic R.F. stage again with 1000 ohms load to raise the usually low R.F. input voltage level of the tapped low impedances to levels of a few volts to ensure efficient demodulation by the diode of V_{15}. After filtering, the rectified response is amplified by the triode of V_{15} and fed to the *Y*-plates of the cathode-ray tube. The switch is in position 1 when the R.F. response is tapped off the amplifier to be aligned. It is in position 2 when the alternative method is employed, viz., when the rectifier incorporated in the amplifier under test is used.

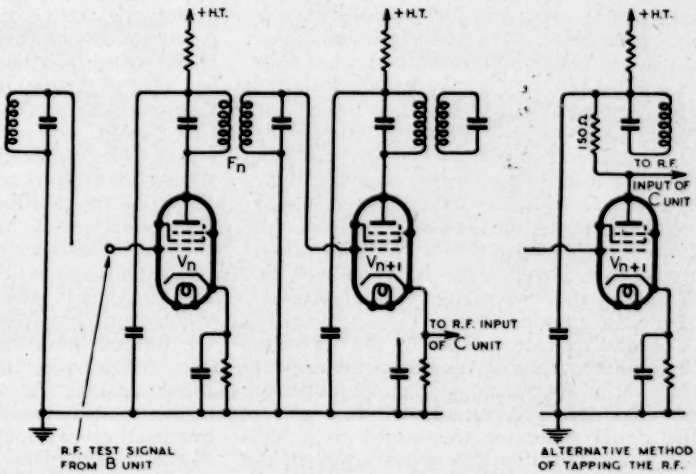
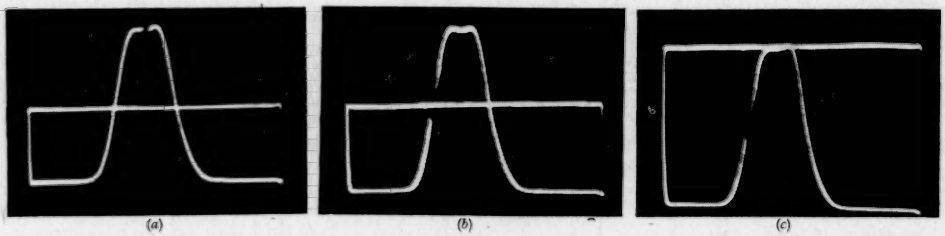


Fig. 11. *Arrangements for aligning a single stage of an amplifier.*

In aligning a multi-stage band-pass amplifier it was found extremely useful to be able

to test and align each individual filter separately before considering the total response curve. This applies in particular to the type of amplifier where the single stages are not meant to have identical filter curves so that the sum-response is the product of a number of carefully adjusted and mutually aligned, but individually different stage filter curves. Here the continuous calibration provided by the B unit proves invaluable as regards both ease of adjustment and saving of time.



(a) (b) (c)

Fig. 12. *(a) Response curve with black mark at the mid frequency, the reference line at arbitrary level. Signal generator settings :—frequency, 5 Mc/s ; attenuator, 1 db. (b) A point on the flank is to be located ; at first the reference line is adjusted through the centre of the black mark so that the signal generator settings are :—frequency, 4.68 Mc/s ; attenuator, 3.7 db. (c) The reference line is adjusted to top level by the signal generator settings :—frequency, 4.68 Mc/s ; attenuator, 12.7 db. The difference between the two attenuator settings is 12.7 − 3.7 = 9 db., i.e., the frequency response at 4.68 Mc/s is 9 db. below maximum response.*

A typical amplifier is sketched in Fig. 11, and two methods are shown by which the R.F. can be tapped if, for example, filter F_n is to be aligned. The R.F. test signal from the B unit is fed directly to the grid of valve V_n and the ordinary grid lead is disconnected. The response can now be taken either from the cathode resistor of V_{n+1}, if the bypass condenser is removed, or by replacing the filter load in the anode circuit of V_{n+1} by a 150Ω resistance and taking the R.F. response off the anode. In both cases the desired R.F. response was made to appear across low impedances in a manner not disturbing the " impedance neighbourhood " of the filter under test.

To demonstrate the use of the apparatus three photographs of the calibrated response trace of a four-stage 5-Mc/s amplifier are reproduced in Fig. 12. In the first picture the signal generator was tuned to 5 Mc/s and the calibration gap appears well in the centre of the total filter curve of the amplifier. The attenuator of the signal generator was set to an arbitrary value. In Fig. 12(b) the signal generator is detuned and its output so adjusted that its amplitude is equal to that of the frequency-sweep generator, both measured at the output of the B unit. If the signal generator were now tuned across the sweep range the gap in the trace would travel along the response curve and the level line would shift up and down always projecting through the calibration gap in the response curve. In Fig. 12 (b) the signal generator was actually tuned to 4.68 Mc/s and its attenuator setting noted as 3.7 db.—the absolute value is irrelevant for this measurement. In Fig. 12 (c) the output of the signal generator was increased until the level line passed through the peaks of the double-hump response curve and its attenuator setting noted as 12.7 db. The result of the measurement, therefore, is : the response of the amplifier at 4.68 Mc/s is 12.7 − 3.7 = 9 db. below maximum response. Since the A.F. amplifier used in the C unit is essentially linear, and not logarithmic, the response curve traced on the screen appears as if plotted in an essentially linear co-ordinate system. It lies in the principle of this measurement that the amplifier under test must operate under strictly linear conditions, for it relies on the fact that, say, twice the signal generator voltage put into the B unit produces twice the output from the amplifier under test. The following rectifier and A.F. amplifier, however, may be non-linear in its characteristics — only excluding the case of overloading—without impairing the accuracy of the measurement. The net result of such non-linearity would be merely a deformation of the response curve on the screen in the Y-direction. It is also evident that the response curve is still measurable by means of the method illustrated in Fig. 12 at off-tune frequencies corresponding to the flat

bottom portions of the trace, the only limitations being the amplitude calibration range of the B unit (20 to 30 db.) and non-linearity of the amplifier under test.

4. Conclusions

The apparatus described was developed for a variable bandwidth I.F. amplifier operating at a carrier frequency of 5 Mc/s. Bandwidth variations were achieved by interchanging the bandpass filters; each filter was enclosed in a screened box and altogether four band-pass filters of the tuned-transformer type belonged to one set, representing one bandwidth. The damping resistances necessary to achieve a certain bandwidth were calculated and connected. With the aid of the apparatus described each set of filters was then aligned by adjusting eight tuning condensers and four mutual coupling settings to their optimum value, and the time spent on one set of four band-pass filters was about half an hour.

The advantages of the apparatus are obvious, and its applications are certainly not limited to the case quoted. For ordinary broadcast amplifiers working at 465 kc/s the frequency calibration will no longer operate reliably for reasons explained in paragraph (2.2). The amplitude calibrator can, however, indirectly be used also for frequency indication in the following way: establish the condition when F.M. and steady signal have equal amplitudes at the input of the amplifier under test. This can be achieved by tuning the signal generator through the frequency range traced, and adjusting its attenuator such that the maximum height of the level line, which will occur at least at one frequency, coincides with the maximum height of the response curve. Under this condition the level line would always project through the gap as explained in connection with Fig. 12 (b) if there were a gap, i.e., if the frequency calibration were in operation. However, since no gap is produced the point of intersection or contact between level line and response curve will indicate the frequency. There will generally be more than one such point but the identity

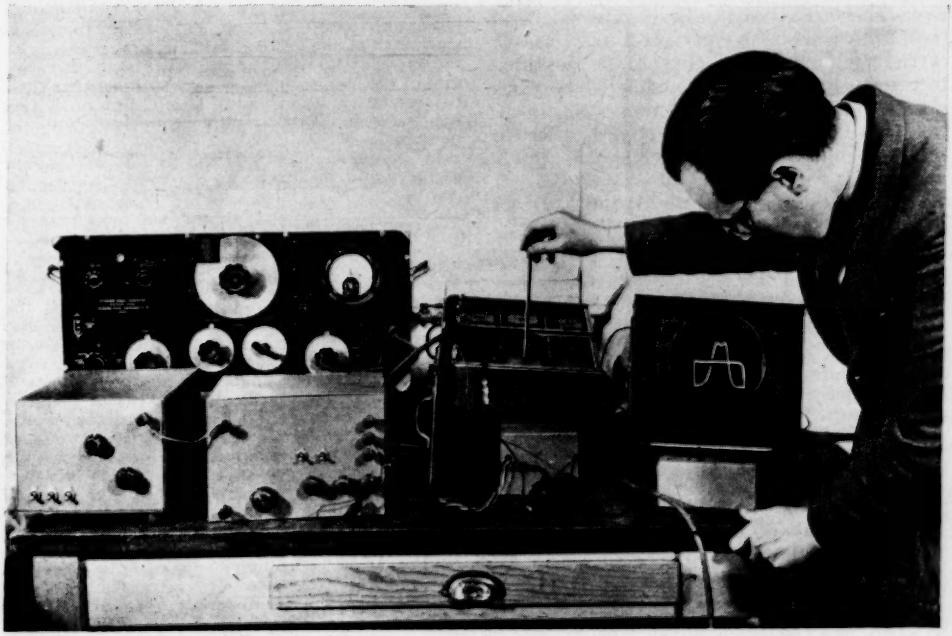


Fig 13. *Photograph of the complete apparatus in operation. A, B and C units can be seen in front, and behind them the signal generator and the amplifier under test, the last filter of which is being aligned. The cathode-ray tube showing the calibrated response curve can be seen at the right.*

of the true frequency indication can easily be established by tuning once through the whole frequency range provided one has found out which X-direction on the screen corresponds to, say, increasing frequency (an asymmetric response curve will offer a quick answer for it).

The main applications of the apparatus described will, however, be in the higher frequency region as occurring in frequency-modulation receivers working at high intermediate frequencies round about 5 Mc/s. It must be mentioned in this connection that the advantages for the alignment of the frequency discriminator are particularly pronounced since the linearity of the discriminator characteristic can be directly and instantly checked on the screen of the C.R.O.

As a last example of the many applications of the calibrated response curve tracer, the alignment of television I.F. amplifiers, and in particular of those for vestigial sideband reception should be mentioned. The peculiar response curve strived at in vestigial sideband reception, with its 50 per cent. response at carrier frequency, etc., has to be adjusted to rather close limits if overshoot distortions are to be kept at a minimum. The continuous and quantitative record afforded by the apparatus described should prove valuable in this instance.

The author wishes to thank the Director of the British Electrical and Allied Industries Research Association for permission to publish this paper.

APPENDIX

It is interesting to consider in closer detail the beat produced in the mixer V_{10} under various conditions. The beat is determined by the value of the frequency sweep Δf_s, by the speed of the rotating capacitor and by the mixer load R_5C_6. Assuming a linear frequency sweep the following diagram (Fig. 14) is almost self-explanatory. At the time $t = t_0$ the beat frequency is zero, after one second the beat frequency would be $\frac{\alpha}{2\pi}$ if the sweep were continued in one direction. If τ_1 be the duration of the real sweep (one-quarter revolution of the motor shaft) and τ_2 the time, counted from zero beat, at which a certain audio pitch $\frac{\omega_a}{2\pi}$ has been reached, the following proportion will hold:

$$\frac{\alpha}{1} = \frac{2\pi\Delta f_s}{\tau_1} = \frac{\omega_a}{\tau_2} \quad \text{or} \quad \frac{\tau_2}{\tau_1} = \frac{\omega_a}{2\pi\Delta f_s} = \frac{f_a}{\Delta f_s}$$

Recalling that the R_5C_6 load of the mixer gives an audio response that drops with rising pitch, $f_a = 1/2\pi R_5C_6$ may be interpreted as that audio frequency at which the response is 3 db. below zero frequency response. Hence the shape of the rectified beat (Fig. 9i) is characterised by the location of f_a with respect to zero beat, or its width may be defined as $2f_a$. Consequently $\Delta f_s/2f_a$ is a measure of the accuracy which can be obtained regarding the synchronisation of the multivibrator, hence the accuracy of the frequency calibration. The above equation shows that for a given mixer load R_5C_6 and frequency sweep Δf_s the calibration accuracy is independent of the motor speed; for

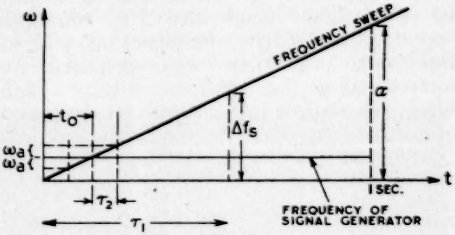


Fig. 14.

$2\tau_2/\tau_1$, representing pulse duration referred to sweep duration, is a constant.

There are, however, four more points to be taken into consideration.

(1) Since the amplitude of the signal generator is varied in the process of calibration the hump or pulse amplitude varies too, and so does the shape and width of the locking pip (Fig. 9j) appearing at the anode of V_{12} (see Fig. 8). But the width variation of the locking pip is considerably smaller than the height variation of the hump (Fig. 9i). This was borne out both by graphical computation and by experiment.

(2) As the frequency of the beat is $\alpha(t - t_0)/2\pi$ the equation for the momentary beat voltage v_b will be:

$$v_b = \cos\int_{t_0}^{t} \alpha(t - t_0)dt = \cos\frac{\alpha}{2}(t - t_0)^2,$$

a function symmetrical with respect to $t = t_0$. The function for $t \geq t_0$ is depicted in Fig. 15(a) as it would appear on the screen of the C.R.O. if the anode voltage of the mixer V_{10} were fed to the Y-plate. Assuming the amount of frequency sweep Δf_s constant, say one megacycle per second from minimum to maximum oscillator frequency, doubling the motor speed whilst keeping the scan amplitude in the X-direction constant would produce an oscillogram like Fig. 15 (b). It can be seen that the two beats are different though having exactly the same envelope. The latter is determined by the momentary pitch of the beat as already explained, and it can be checked by inspection that the 3 db. amplitude drop occurs at the same displacement X on the screen corresponding to the same momentary pitch. The distance between the two successive zero points of the function is an approximate measure of the reciprocal of its momentary pitch. This is Δx in Fig. 15 (a) and $2\Delta x$ in Fig. 15 (b), but since the beam moves twice as rapidly in the second case the distances in question are equal to one another if expressed in time, hence the momentary pitch at the displacement X on the screen is the same in both cases—and yet the two beats look different. It becomes clear from the study of Fig. 15 that the speed of the motor cannot be increased indefinitely, for fewer and fewer oscillations would then appear within the interval X. Since no ideal and practic-

able amplitude demodulator is known which would record the momentary vector amplitude, and as amplitude demodulation by means of a rectifier in practice always means a compromise of the discrimination between the carrier and the modulation frequency, demodulation will become more uncertain with higher speeds.

(3) The exact shape of the beat, particularly around zero frequency, depends critically on the phase between constant and variable frequency. Since both frequencies are in no way coherent the phase will be erratic. It is shown in Fig. 9 (h) that two successive beats have different trends around zero beat. This adds another uncertainty to the synchronising hump which weighs more heavily as the speed increases.

(4) Finally the possible influence of F.M. transients may be mentioned. Up to now it has been assumed that the amplitude response of the mixer load to the beat was governed by the momentary frequency of the beat. This is not quite so, for the frequency characteristic of a network is strictly defined as the response to a steady frequency which, theoretically, may only be varied infinitely slowly if the whole frequency range is to be covered. For finite changes of frequency an F.M. transient is superimposed upon the steady state response. As an illustration it may be mentioned that the F.M. response of a crystal filter will differ widely from its sharp "steady state" response, as the crystal, owing to its very high Q, will be excited to ringing when the impressed frequency sweeps fast enough past its natural resonance. Fortunately in the present case the F.M. transients proved to be negligibly small, but it is important to be aware of them, and hence adjust parameters in such a way that the influence of F.M. transients upon operating conditions is kept harmless.

All four points indicate that the speed of the condenser rotation should be kept as low as possible so that its optimum value will depend on a compromise between the flicker of the picture on the C.R.O. screen demanding higher speeds and the aforementioned considerations demanding lower speeds.

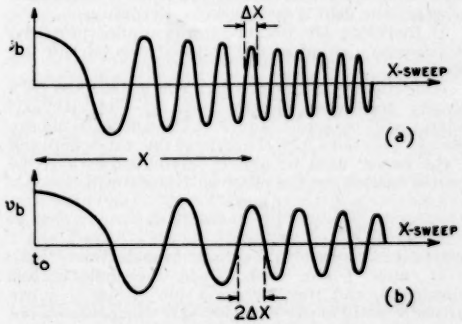


Fig. 15.

Note.—Since the first publication in E.R.A. Report M/T79 of the material presented in this paper, an interesting paper was published in *Electronics*, May 1944: "Automatic Calibration for Frequency Meters," by D. Sunstein and J. Tellier elaborating the principle of beat calibration, although for entirely different operating conditions.

As to F.M. transients, see "Variable Frequency Electric Circuit Theory," by J. R. Carson and T. C. Fry, *Bell S. Tech. Journ.*, Oct. 1937.

Correspondence

Letters of technical interest are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Frequency Modulation

To the Editor, "Wireless Engineer"

SIR,—D. A. Bell's letter in your February issue presents an account of the performance of frequency-modulation receivers with respect to impulsive interference which appears to be a little oversimplified.

In the presence of an unmodulated carrier to which the receiver is considerably mistuned, powerful impulsive interference of constant amplitude produces in the receiver output pulses, whose amplitude is constant and proportional to the degree to which the receiver is mistuned (as stated by Mr. Bell), but whose duration increases as the amplitude of the interference increases. The audible output, which depends on the time-integral of the pulse, thus increases as the level of the interference increases.

As the receiver is brought into tune with the carrier the amplitude of the individual pulses in the receiver output does not remain constant, and when the receiver is in tune the output pulses appear to have a random distribution of amplitudes in both positive and negative directions equally. The pulse width also decreases and the audible output from the receiver in the tuned condition is small compared with that in the mistuned condition. Nevertheless, when strong interference is present this minimum noise output is by no means a negligible quantity.

It has been assumed in the foregoing remarks that the receiver output is proportional to the instantaneous frequency of the composite wave applied to the detector (discriminator) circuit. In most receivers the low-frequency circuits will be unable to reproduce short pulses, and the receiver output will then appear as pulses of constant (usually exponential) shape whose amplitude depends on the time-integral of the applied pulse.

A. S. GLADWIN,
G. T. THOMPSON.
Research Laboratories of the General Electric Company, Ltd., England.

Signal/Noise Ratio

To the Editor, "Wireless Engineer"

SIR,—I feel that some misconceptions may arise from one of the conclusions of Mr. R. E. Burgess in his paper (in the February issue) on the subject of Signal/Noise Ratio for three alternative methods of coupling the first valve of an amplifier to the aerial.

Mr. Burgess considers only the case where the input resistance (R_g) of the valve V is infinite relative to that of the secondary of the transformer or tuned circuit (R_2). On this basis he correctly concludes that "when the resistance of the source exceeds a certain value [$R_2/4$] it is better to connect it direct to the valve than through a transformer."

In practice, however, the only case where the aerial or feeder resistance R is likely to be any large fraction of the dynamic resistance between grid and earth (with tuned circuit connected) occurs on

very short waves where R_g is low, and usually much smaller than R_2. If we recalculate his results for this case, we find that the formulae and curves for transformer connection [(b) in his Fig. 7] and for cathode input valve coupling [(a) in his Fig. 7] are unaltered provided only that we substitute R_g for R_2. In the case of direct connection from source to grid, however, the formula is modified as follows: (R_0' is valve equivalent noise resistance).

Loss in Signal/Noise Ratio

For $R_g \gg R_2$ (Burgess) $1/\sqrt{1 + R_0'/R}$

For $R_2 \gg R_g$ $1/\sqrt{1 + R/R_g + \frac{R_0'}{R}(1 + R/R_g)^2}$

On drawing a series of curves from this formula and from the formula for transformer connection, it is found that the latter is always superior, with the one exception of the case where $R_0' > R$ and R_g is of the same order as R, when the two arrangements become roughly equal in merit. This conclusion accords with common sense since the ideal transformer will not introduce any appreciable noise or loss provided $R_2 \gg R_g$: on the other hand, it cannot introduce much selectivity either, and hence some compromise may be necessary between signal/noise ratio and selectivity (e.g. by tapping down the grid).

There is in practice, unfortunately, a further complication in that the effective temperature of R_g is usually of the order of two or three times room temperature due to the contribution of transit time effects to the total valve input loss. (See North. *Proc. I.R.E.*, February, 1942). The resulting formulae are too complicated and too indeterminate to be worth reproducing here, and we can only observe that this point will tend to increase the divergence of practical results from those obtained when R_g is neglected.

M. V. CALLENDAR.

Southend-on-Sea, Essex.

Metric or Bedlam?

To the Editor, "Wireless Engineer"

SIR,—The mention of the nautical mile of 2029 yards in my previous letter (February, page 74) tempts me to release a provocative bee—B2—from my bonnet. Others may follow if space and Editorial patience permit.

Submarine cable engineers may use a peculiar unit of length, but at least they stick to it like glue. Cable landlubbers vacillate between the statute mile, 1,000 yards, 100 feet, and, all too rarely in Britain, the kilometre or metre. Opportunities are surely being missed in the chain and the 10,000 inches! If the 1,000 yards and 100 feet are really preferred, why not call them the kiloyard and hectofoot? The former is quite euphonious, and I have occasionally used it in gentle irony. But after working through a Service specification containing no less than five different units of length, I have felt like quoting pressures in pennyweights per square hand, and attenuations in percentage diminutions per rod, pole or perch. More than irony is needed to stop this rot.

In passing, may I be so ungrateful as to say I find the decibel slightly inconvenient? Dare we use bels and millibels? If we *must* retain our feet despite their paining us, then the mb./ft. is easier to manipulate, besides shorter and more pleasing, than the db./100 ft.!

The great development of h.f. cables during the war is a golden opportunity to introduce the metric system in this field at least, and the good example might be contagious. Now, when the customer takes all one can produce, and asks for more, is the time to suggest that he may *not* always be right. But the customer is not the only culprit: the producer shares the blame. One fundamental cause may be that executives rarely do the calculations, and when they do they wisely have them checked.

This is not a matter of small importance. Could it be computed, the aggregate skilled man-hours wasted in making and checking unnecessary conversions of units might be startling. When the inevitable mistakes, and the trouble thereby caused, are taken into account, the result is obviously serious. And the effect on the temper is peculiarly exasperating, perhaps because the bother could so easily be avoided by a little forethought.

In a passage still readable with profit, and likely to remain so for another fifty years, Heaviside (*Electrician*, October 16th, 1891; *E.M.T.*, Vol. 1, p. 122) remarked on the perversity of the practical British engineer. But what of the weakness of the research engineer in failing to insist on such a needed reform?

A. L. MEYERS,

London, S.E.10. (T.C. & M. Co., Ltd.)

Deflected Electron Beams

To the Editor, "Wireless Engineer."

SIR,—Mr Rodda, in your February issue, says that equation (31) of my paper in the June, 1944, *Wireless Engineer*, is inadmissible in view of the result of an arbitrary test which involves letting the frequency tend to zero. He also says, surprisingly, that deflection power "becomes zero" when $f = 0$. On the contrary, the beam consists of electrons which enter the deflecting field one after the other, and, because each one has to be supplied in turn with enough energy to deflect it, there must exist a rate of flow of energy (= deflecting power) into the system whether the field is steady or is alternating.

If, therefore, Mr. Rodda's test is applied properly, it becomes a proof of the truth of this part of my theory.

Analytically, if an electron beam is deflected by a steady transverse electric field ($f = 0$), its exit energy will be $\frac{1}{2}mv_x^2$ (equal to the entrance energy $\frac{1}{2}mv_0^2$) plus $\frac{1}{2}mv_y^2$.* Therefore the ratio between "the power used to deflect the electrons and the power carried by the electron beam" will be:—

$$\eta_{dc} = \frac{\frac{1}{2}mv_y^2}{\frac{1}{2}mv_x^2} = \left[\frac{dy}{dx}\right]^2 = \tan^2\phi \qquad .. \quad (31.1)$$

where ϕ is, as before, the angle of deflection.

If, now, $f \neq 0$, then, since the deflection is sinusoidal, and the average value of $\sin^2$ is $\frac{1}{2}$, we arrive directly at my equation (31) which was stated to apply to the $f \neq 0$ case), namely:

$$\eta_d = \frac{\frac{1}{2}mv_y^2}{\frac{1}{2}mv_x^2} = \frac{1}{2}\left[\frac{dy}{dx}\right]^2 = \frac{\tan^2\phi}{2} \qquad .. \quad (31)$$

No approximation has been made in deriving the above in a very simple way from classic electromagnetic theory; hence my previous remark to the effect that it is rigorous.

London, S.W.18. J. H. OWEN HARRIES.

* Harries' letter to *Wireless Engineer*, April 1944.

WIRELESS PATENTS

A Summary of Recently Accepted Specifications

DIRECTIONAL WIRELESS

564 934.—Beacon transmitter radiating two overlapping beams wherein both aerials are energised by a single H.F. stage coupled to a series type of modulator.

Marconi's W.T. Co. Ltd.; E. Green; and N. H. Clough. Application date 15th April, 1943.

565 010.—Arrangement and design of a low-loss transmission-line coupling between a short-wave D.F. aerial and a distant radio goniometer.

Aga-Baltic Akt. Convention date (Sweden) 2nd April, 1942.

RECEIVING CIRCUITS AND APPARATUS

564 911.—Superhet receiver in which frequency conversion is effected by the non-linear response of an iron-cored coil to magnetising currents derived from the signal and local oscillations.

Marconi's W.T. Co. Ltd. (assignees of H. L. Donley). Convention date (U.S.A.) 14th April, 1942.

564 917.—Suppressing inter-station noise by means of two diodes coupled respectively to the input and output circuits of an I.F. amplifier.

J. Wardley-Smith. Application date 21st July, 1943.

564 930.—System of press-button tuning, covering several wave-bands, wherein the lateral position of each selector button is varied by the wave-change switch.

Marconi's W.T. Co. Ltd. (assignees of W. R. Koch). Convention date (U.S.A.) 30th May, 1942.

564 957.—Receiver with means for automatically blocking the signal channel against the passage of short pulses of disturbance.

Marconi's W.T. Co. Ltd. (assignees of R. L. Hollingsworth). Convention date (U.S.A.) 17th April, 1942.

565 267.—Frequency-selective device for signalling, in which use is made of the natural periodicity of columns of liquid.

The Siemens and General Electric Railway Signal Co. Ltd. and H. J. N. Riddle. Application dates 16th July and 21st December, 1943.

565 283.—Cross-coupled pair of " see-saw " valves, with a double-throw electronic switching device for counting signal impulses of high or low frequency.

The British Thomson-Houston Co. Ltd. (communicated by the General Electric Co.). Application date 24th March, 1943.

TELEVISION CIRCUITS AND APPARATUS

565 266.—Source of stabilised frequency, comprising a rotating magnetic field, and means for synchronising two such sources, *e.g.*, for facsimile or picture transmission.

Marconi's W.T. Co. Ltd. (assignees of R. E. Mathes). Convention date (U.S.A.) 14th July, 1942.

TRANSMITTING CIRCUITS AND APPARATUS

565 304.—Crystal-controlled valve generator including a phase-splitting device for automatically stabilising the system, applicable to frequency modulation.

Standard Telephones and Cables Ltd. (assignees of G. T. Royden). Convention date (U.S.A.) 4th May, 1942.

565 324.—Group of star-connected condensers for automatically protecting electric impedance networks.

The British Thomson-Houston Co. Ltd. Convention date (U.S.A.) 23rd November, 1942.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

565 063.—Method of coating or screening the glass base or bulb of H.F. amplifiers to prevent capacitance losses.

G. Liebmann and Cathodeon Ltd. Application date 6th January, 1943.

565 099.—Saw-tooth or like oscillation generator in which the repetition frequency is linearly proportional to an applied control current.

B. M. Hadfield. Application date 17th March, 1943.

565 274.—Method of sealing-in a contact-making member, particularly for the deflection plates of a cathode-ray tube.

Marconi's W.T. Co. Ltd. (assignees of K. M. McLaughlin). Convention date (U.S.A.) 16th January, 1942.

SUBSIDIARY APPARATUS AND MATERIALS

564 970.—Construction and mounting of a screw-controlled neutralising or like condenser.

Stratton and Co. Ltd. and H. N. Cox. Application date 20th September, 1943.

564 977.—Upper electrode and protecting structure for the sensitised layer of a dry-contact rectifier of the selenium type.

Standard Telephones and Cables Ltd. (assignees of C. A. Kotterman). Convention date (U.S.A.) 17th October, 1942.

564 980.—Use of thallium and halogenated selenium to increase the rectification ratio of a dry-contact rectifier.

Standard Telephones and Cables Ltd. (assignees of H. S. Denmark). Convention date (U.S.A.) 15th March, 1943.

564 988.—High-frequency switching device utilising the impedance properties of quarter- and half-wave transmission-line stubs.

The General Electric Co. Ltd. and D. C. Espley. Application date 20th June, 1940.

These abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2. Price 1/- each.

ABSTRACTS AND REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

Comparative Length of the Abstracts.—*It is explained to new readers that the length of an abstract is no sign, by itself, of the importance of the work concerned. An important paper in English may be dealt with by a short abstract, or even, if it is in a journal readily obtainable, by a square-bracketed addition to the title; while a paper of similar importance in a language other than English may be given a long abstract. In addition to these questions of language and accessibility, the nature of the work has, of course, a great effect on the useful length of its abstract.*

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PROPAGATION OF WAVES

1007. DISCUSSIONS ON "WAVE GUIDES IN ELECTRICAL COMMUNICATION" [3249 of 1943].—J. Kemp. (*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 145–155.)

Among the very many points dealt with at the London Discussion alone are the following:—Anomalous behaviour of tubes of the London Underground Railways, *and* problems to be solved before guides can replace balanced or coaxial lines in line communication (Gill: *cf.* Strong, in Discussion of Edwards's paper, 1109, below): unwarranted strictures on Huygens's principle (Lamont [and *cf.* Potier, 648 of 1942]): comparison with coaxial cables as regards attenuation, *and* unsolved problems connected with propagation along the earth's surface (Smith-Rose [and *cf.* Polić, 386 of February]): attenuation, *and* repeaters (Jarvis): production of waves of other modes from a wave of given mode, *and* behaviour of the grating discriminator (Sturley): impedance in wave-guide theory, and the special properties of the H_o wave (Turney: "very important" as regards the guide *versus* cable problem): *are* there hills and dales of potential advancing over the surface of the earth when a long wave spreads out from an aerial? (Fortescue): relationship between wave-guide and concentric-line propagation (Willshaw): suggestion to reduce size of guide for given frequency by capacitive loadings (Wickson: the author's reply comments "promises electrical and mechanical advantages"): recent "*TM*", "*TE*" nomenclature in America (Howard): "an electric field always appears to me as a sort of disembodied spirit until it has been related to the electric charge from which it derives its being"; the guide-sheath as the limit of a closely-packed array of longitudinal aerials (Moullin): the mechanism of the launching of a wave from supply cable into guide (Taylor). Many speakers deal with the use of the terms "phase" and "group" velocities.

Points in other Discussions include an advantage of the rectangular cross-section, *and* the limitations of the coaxial wavemeter (Miller): care necessary in analysis in terms of the impedance concept (Willis Jackson): concept of patterns and loops of force form an unsatisfactory approach (Silberstein).

1008. EQUIVALENT CIRCUITS OF THE ELECTROMAGNETIC FIELD [Article on Kron's Recent Work, 2838 of 1944 & Back References].—S. A. Stigant: Kron. (*BEAMA Journal*, Nov. 1944, Vol. 51, No. 89, pp. 365–369: Dec. 1944, No. 90, pp. 412–416.)

1009. ON THE VERY HIGHS [Relations between V.H.F. & U.H.F. Signals and Meteorological Conditions].—E. P. Tilton. (*QST*, July 1944, Vol. 28, No. 7, pp. 42–45.) For previous work *see*, for example, 394 & 2114 of 1944.

1010. ENERGY IMPARTED BY ACTIVE NITROGEN [Conflict between Spectroscopic Evidence & Rayleigh's Results (from Study of Incandescence of Metals) explained by Writer's Active Nitrogen Hypothesis (410 of February & Back References)].—S. K. Mitra. (*Nature*, 30th Dec. 1944, Vol. 154, No. 3922, p. 831.)

1011. COEFFICIENT OF RECOMBINATION OF N_2^+ (X') IONS AND ELECTRONS IN THE AFTER-GLOW OF ACTIVE NITROGEN [in connection with Mitra's Hypothesis: Use of Rayleigh's Rate-of-Decay Measurements for Calculation of Coefficient: $\alpha = 4 \times 10^{-14}$ cm^3/s].—J. S. Chatterji. (*Sci. & Culture* [Calcutta], Oct. 1944, Vol. 10, No. 4, p. 176.) For Mitra's work *see* 1010, above.

1012. HISSING SOUNDS HEARD DURING THE FLIGHT OF FIREBALLS [and the Simultaneity of the Light & Sound Phenomena].—M. A. R. Khán. (*Nature*, 13th Jan. 1945, Vol. 155, No. 3924, p. 53.) For previous work *see* 392 of February.

1013. EFFECT OF [Partial] SOLAR ECLIPSE ON THE IONOSPHERE [Calcutta Observations of the Eclipse of 20th July, 1944 (for Kunming Observations of Amplitude Variations of E-Layer Reflections during the Same Period *see* 714 of March)].—S. S. Baral & S. N. Mitra. (*Sci. & Culture* [Calcutta], Oct. 1944, Vol. 10, No. 4, pp. 175–176.)

"On the day of the eclipse, during the hours preceding the start of the eclipse the ionisation of Region E was found to be slightly less, and that of Region F_2 slightly greater, than the average ionisation as recorded from the control observations. With the progress of the eclipse, however, the ionisation of both the regions fell below the normal values. For Region E the ionisation decreased smoothly and the minimum was attained 10 minutes after the eclipse maximum. The minimum of ionisation was about 43% below the normal value. For Region F_2 the max. decrease observed was 30% and it occurred 14 minutes after the eclipse had reached its maximum.

"Fig. 1 depicts the sharp minimum in the ionisation of Region E. For the case of Region F_2 (Fig. 2), however, the minimum is not as marked as in the case of Region E, though the ionisation is found to be depressed appreciably below the normal value during the [whole] eclipse period."

1014. CORONAL STRUCTURE AND THE RELATIONSHIP BETWEEN CHROMOSPHERIC AND CORONAL PHENOMENA DURING THE SOLAR ECLIPSE OF 19TH JUNE, 1936.—S. Vsessviatsky & E. Bougoslavsky. (*Nature*, 30th Dec. 1944, Vol. 154, No. 3922, p. 834: summary, from *Mon. Not. Roy. Astron. Soc.*, 1944.) *See* also 1015, below, and 3313 of 1940.

1015. CONNECTION BETWEEN FACULAE AND GEOMAGNETIC ACTIVITY [Sternberg State Astronomical Institute's Observations & Their Results].—E. R. Mustel. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Jan. 1944, Vol. 42, No. 3, pp. 112–115: in English.)

In Feb. 1942 the writer was able to reveal the following relation: "every facular field passing through the apparent centre of the sun's disc was found to be accompanied by disturbances of a certain strength which may sometimes be considerable." Use was made at once of this fact as one of the principal indices for forecasting geomagnetic and ionospheric disturbances. The former were forecast by the facular-field method "with an accuracy of up to 24 hours or occasionally even up to 12 hours."

Further close investigation was carried out and the results are reported here. The main conclusion reached is that the disturbances usually associated with sunspots are really "connected with the facular (floccular) fields rather than with the spots proper. The rôle of the spots, as of formations characterised by considerable magnetic fields, is reduced to merely deflecting the charged corpuscles ejected directly from the faculae, on account of which the radial motion of those corpuscles may be disturbed . . ." Thus in a few cases when facular fields were observed to pass through the apparent centre of the disc, but failed to produce geomagnetic disturbances, those fields were invariably found to comprise sunspots, which are considered to have deflected the corpuscles away from their normal direction. On the other hand, disturbances coinciding with the passage of sunspots through the central meridian of the sun, but *not* through the centre of the disc, are attributed to the corpuscles ejected by faculae surrounding these spots and deflected earthwards by the spots. The few cases when faculae passing the central meridian, but *not* the disc-centre, produced disturbances in spite of the apparent absence of included sunspots are explained by the deflecting action of spots of the "invisible" type often present in flocculae. Of the cases (presumably rare?) when "a whole array of facular regions" passing across the disc-centre, but enclosing sunspots, were found to produce "magnetic disturbances of various strength," it is remarked that "in this connection the sunspots may be considered as a certain disturbing factor."

The "centre-of-disc" relationship stated at the beginning of this abstract (a rule bearing no pronounced statistical character, unlike the "sunspot-meridian" rule) was revealed particularly clearly in 1942, the year in question, because geomagnetic activity was very intense and there were rather few sunspots. Around the sunspot-maximum period it evidently, from what has been said above, would not hold good. Only those disturbances connected with corpuscular emissions (not with strong increases of ultra-violet radiation) are considered. Goodall's "close relation" between F_2 critical frequencies and floccular-activity values (3437 of 1939) is referred to. The Soviet expedition's coronal plates (1936 total eclipse: *see* 1014, above) and their revelation of a radial outflow of coronal matter in the equatorial regions above the flocculae, in powerful streamers, are quoted.

"The life-time of some of the facular regions which were observed in 1942, and recurred at each revolution of the sun, goes fully to account for the 27-day recurrence tendency in magnetic conditions, which was rather sharply expressed in 1942. And it could by no means be interpreted in this case from the viewpoint of sunspot activity." Nor could the seasonal character of the geomagnetic activity, clearly expressed in 1942 and related to the change in the heliographic latitude of the apparent centre of the disc; but the present results fully account for this also.

1016. SUNSPOTS AND ASSOCIATED PHENOMENA [Summary of Bowerman's Article "Sunspots in Review"].—W. G. Bowerman. (*Nature*, 30th Dec. 1944, Vol. 154, No. 3922, p. 821.)

1017. DEVELOPMENT OF INTERACTIVE SOLAR PROMINENCES [Rare Form of Active Type in which Two or More Prominences are connected by Streamers].—E. Pettit. (*Scient. Monthly*, March 1944, Vol. 56, No. 3, pp. 293–294.)

1018. GEOPHYSICS AND GEOMORPHOLOGY IN U.S.S.R. [Note on Three Numbers of *Bull. de l'Acad. des Sci. de l'URSS*, Série Géographique et Géophysique].—S. I. Tom-

keieff. (*Nature*, 11th Nov. 1944, Vol. 154, No. 3915, p. 619.)

One paper mentioned is by S. L. Ponisovski, discussing the state of the E layer at twilight. In another paper A. J. Driving & others, in a study of the polarisation and absorption of light in natural fogs, report a discrepancy between theory and observation which they propose to solve by postulating the presence of submicroscopic droplets. The effectiveness of synoptical weather predictions is discussed by M. A. Omshansky.

1019. Illumination of a Horizontal Plane at Twilight and at Night [Observations for D Values from 0° to 18° and Various Cloud Conditions].—W. W. Scharonow. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th March 1944, Vol. 42, No. 7, pp. 296–300 : in English.)

Among other results, it was found that at every value of D the horizon was rather brighter in the North than in the South, probably owing partly to the constant presence of a weak aurora and partly to zodiacal light. Values of the "weather coefficient" for summer and winter are given in Table 4. The measurements were made at Elabuga ($\lambda = 3^h\ 28^m$, $\phi = 55.8°$) in 1942.

1020. Influence of Clouds upon the Magnitude of Solar Radiation and of Radiation scattered by the Atmosphere.—N. N. Kalitin. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Jan. 1944, Vol. 42, No. 2, pp. 65–69 : in English.) For previous work *see* 401 of February.

1021. Point Source of Light between Parallel Planes.—V. V. Sobolev. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Feb. 1944, Vol. 42, No. 4, pp. 172–173 : in English.)

"If a luminous source is placed near to reflecting surfaces, the illuminations cannot be properly ascertained without taking into account the repeated reflections from these surfaces. Generally speaking, the problem is reduced to the solutions of an integral equation. Below is discussed a case when the solution is obtained in the explicit form." The intervening space is taken as perfectly transparent, but the method is applicable when an absorbing (but not scattering) medium is involved.

1022. Screens with Uneven Surfaces [Mean Brightness may be Many Times that of Plane Screen].—Antonov-Romanovsky. (*See* 1145.)

1023. Lunar Coronae [in Alto-Cumulus Cloud : and Some Calculated Diameters of Cloud Droplets].—J. C. W. De la Bere. (*Nature*, 11th Nov. 1944, Vol. 154, No. 3915, p. 613.)

1024. Degree of Polarisation of Light on Lateral Radiation.—A. Gershun. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Nov. 1943, Vol. 41, No. 6, pp. 239–240 : in English.)

"The loss of energy by reflection on passing through the surface of the radiating body depends upon the direction of the electric vector. Therefore the light emitted to the outside is polarised even when each elementary volume gives out non-polarised light . . . When allowance is made for repeated refractions, formula 4 holds for a plane-parallel radiating dielectric layer of any thickness great in comparison with the wavelengths involved."

1025. The Extension of the Heaviside Expansion Theorem to the Equations of Engineering and Physics in Curvilinear Orthogonal Coordinates.—J. J. Smith. (*Journ. Franklin Inst.*, Oct. 1944, Vol. 238, No. 4, pp. 245–272.)

From the General Electric Company. Heaviside's methods "have not as yet been developed to such a degree as to be employed in field problems that require partial differential equations with more than two independent variables," such as those connected with the propagation of electromagnetic or elastic waves in dissipative media, the distribution of flux in the air-gap of electrical machinery, etc. "This paper undertakes to solve such problems by operational methods similar to Heaviside's, in those types of coordinates of the greatest usefulness to engineers, namely curvilinear orthogonal coordinates. The result is given in formulae which are broader than the Expansion Theorem, being applicable to one, two, or three dimensions, and include the Expansion Theorem as a special case . . . It is further shown that by restricting the type of problem to a certain form (the Green's Function), basic solutions of one, two, or three dimensional equations of the type specified can be expressed in the form of separate functions for each of the variables. These separate functions can be listed in tables similar to tables of integrals and will have a corresponding value in eliminating repetition in mathematical operations . . ."

1026. Propagation of Waves on the Surface of an Infinitely Long Circular Cylinder conceived as a Cut-Out Portion of an Infinitely Elastic Space.—J. A. Mindlin. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Feb. 1944, Vol. 42, No. 4, pp. 151–155 : in English.)

"For a given radius of the cylinder the wave motion along its surface ranges in velocity from the Rayleigh wave to transverse waves. Accordingly, the range of wavelengths is from 0 to $2\pi qbR$, where q is the root of eqn. 20, and b the velocity of transverse waves." The subject of forced oscillations (Lamb's problem) will be discussed in a later Note.

1027. A Contribution to the Theory of Long Waves [in a Heavy Fluid : Rayleigh Waves, etc.].—M. A. Lavrentieff. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Dec. 1943, Vol. 41, No. 7, pp. 275–277 : in English.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

1028. Cosmic Static.—G. Reber. (*Astrophysical Journ.*, Nov. 1944, Vol. 100, No. 3, pp. 279–287.)

Preliminary results of these researches have already been published (336 of 1943 and back references), but during 1943 "new and improved apparatus was put into operation and considerably better data were obtained." A 31.4 ft mirror with a focal length of 20 ft captures the energy and directs it to a drum, at the focal point, con-

taining a pair of cone antennae. On the far end of the drum is mounted a 5-stage amplifier with about 90 db gain over a range 156–164 Mc/s, whose output is rectified by a diode and led through a concentric cable to the recorder. The random-charge voltage from the first amplifier stage is also rectified by the diode: its constant d.c. value serves as a reference level for the calibration of the intensity of the cosmic static (being noted on a meter before and after a set of observations), but during the actual taking of data it is cancelled out by a small battery so that the static may be perceived more easily.

About 200 charts were obtained in 1943: the final results, plotted on a flattened globe, are shown in Figs. 4a & b for the two hemispheres of the sky, the constant-intensity lines being plotted in terms of 10^{-22} watt/sq.cm/circular degree/Mc band. "Too little is known about the cause of this phenomenon to read a great deal from Fig. 4. However, it is suggested that this disturbance is in some way connected with the amount of material in space. Since the wavelength is long (1.87 m), the absorption caused by dust is small. Therefore the intensity is roughly indicative of the amount of material between us and the edge of the Milky Way. On this basis the various maxima point to the directions of projections from the Milky Way. These projections may be similar to the arms often photographed in other spiral nebulae. In the case of the Milky Way this general picture would call for the centre towards Sagittarius and arms in the directions of Cygnus, Cassiopeia, and Canis Major. A minimum occurs in Perseus, indicating that we are nearest the edge of the galaxy in that direction . . ."

The new apparatus was sufficiently stable to allow data to be taken during the day to test the suggestion that this long-wave radiation may be set up in the solar corona: it was found that the sun gave "the rather surprising centre intensity" of 10 of the above units. But the writer explains why, in spite of this high value, this source must be greatly discounted when looking for the origin of cosmic static. The spiral in Andromeda seems to be at the threshold of sensitivity of the present apparatus, namely 0.2 of the above unit.

1029. THE INITIATION OF LONG ELECTRICAL DISCHARGES [Further Consideration of the Glow/Arc Transition Theory of the First Leader Stroke].—C. E. R. Bruce. (*Proc. Roy. Soc.*, Ser. A, 30th Nov. 1944, Vol. 183, No. 993, pp. 228–242.)

"It would appear that the existence of currents of this order [the heavy corona currents which must flow laterally from the leader-stroke channel: *see* 2364—and 2993—of 1941] rules out the possibility of the aging of the ionisation in the leader-stroke channel, envisaged by Schonland, and also the recombination theory of the stepped structure of the first leader stroke as it has been developed by Meek and Loeb.

"It is also evident that the only type of electric discharge capable of carrying the large currents which are thus seen to flow steadily in the leader stroke is the arc discharge, and the realisation of this fact has led to a new theory of the stepped leader stroke."

The low values of the electric field required to cause a lightning flash, of the order of one or a few hundred volts/cm, put forward in the first paper, are confirmed. Among other results, it is seen that formulae derived from laboratory studies of corona currents from wires and pointed conductors can be extrapolated to lightning voltages (*i.e.*, over a range of about 1000 to 1), and that the protective range of a lightning conductor or tall building may be expected to increase with the current in a lightning flash (p. 237, top). For Bruce & Golde's paper, also referred to, *see* 966 of 1942 and 2309 of 1943.

1030. AN EXAMPLE OF FUSION OF SOIL BY AN ELECTRIC ARC [caused by Power-Line Breakage: Material formed is similar to Fulgurites].—K. Ver Steeg. (*Scient. Monthly*, Aug. 1943, Vol. 57, No. 2, pp. 191–192.)

PROPERTIES OF CIRCUITS

1031. THE SOLUTION OF TRANSMISSION-LINE PROBLEMS BY USE OF THE CIRCLE DIAGRAM OF IMPEDANCE.—Willis Jackson & L. G. H. Huxley. (*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 105–116: Discussions pp. 117–127.) The full paper, a summary of which was dealt with in 1871 (and *see* 3381 & 3783) of 1944.

1032. ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE [including the Case of a Wave Guide or Transmission Line: Editorial].—G. W. O. H. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 53–55.)

1033. EQUIVALENT CIRCUITS OF THE ELECTROMAGNETIC FIELD [Article on Kron's Recent Work, 2838 of 1944 & Back References].—S. A. Stigant: Kron. (*BEAMA Journal*, Nov. 1944, Vol. 51, No. 89, pp. 365–369: Dec. 1944, No. 90, pp. 412–416.)

1034. THE ELECTRIC FIELD OF THE OPEN TURN [taken as an Infinitely Long Split Cylinder].—W. Bader. (*Elektrot. u. Masch.bau*, 9th July 1943, Vol. 61, No. 27/28, pp. 305–311.)

1035. BAND FILTER FOR ULTRA-SHORT WAVES [D.R.P.741 428 of 14/11/1940]. — Anon. (*T.F.T.*, May 1944, Vol. 33, No. 5, p. 105.)

"Band filters for u.s.w. are already known, consisting of several inter-coupled cavity resonators, usually in the form of a tube with varying cross-section or with branches. The band filter covered by the present invention consists of a coaxial line short-circuited at both ends and so proportioned, as to its length and the ratio of the radii of the inner and outer conductors, that a natural wavelength of the cavity-oscillation type and a natural wavelength of the Lecher type are close to each other."

1036. BAND-PASS FILTER ON THE CHAIN PRINCIPLE, BUILT UP FROM SECTIONS MATCHED AS REGARDS CHARACTERISTIC IMPEDANCE BUT WITH DIFFERENT BEHAVIOURS AS REGARDS ATTENUATION, AND COMPOSED ONLY OF PARALLEL-RESONANCE CIRCUITS.—Anon. (*T.F.T.*, May 1944, Vol. 33, No. 5, p. 106.) D.R.P.744 150 of 9/7/1936.

1037. Insertion Loss of Filters: Half- and Single-Section, Low-, High-, and Symmetrical Band-Pass with or without Dissipation, terminated by the "Design" Resistance [Extensions of C. W. Miller's Paper].—D. G. Tucker: Miller. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 62–71.)

From the P.O. Research Station. It is shown that if Miller's frequency function K (*see* 2155 of 1944) is suitably stated, all his formulae for single-section low- and high-pass filters apply equally to symmetrical non-dissipative band-pass filters: although band-stop filters are not actually considered in the present paper, they also can be dealt with by the formulae.

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Vol. 91, No. 16, pp. 194–205: Discussion pp. 205–208.)

The full paper, summaries of which were referred to in 2557 of 1944. The discussion included a plea for a redesigned undulator (50 spare parts have to be carried) and in fact a redesigned technique: frequency diversity (and its use in Australia): light-operated devices to replace undulators: high directivity: "blocking" effects: "dumb-bell" fading: communication-type receivers: and other points.

1059. Directive Reception—an Answer to Post-War QRM? A Problem for the Experimenter.—Read. (*See* 1069.)

1060. Interference Suppression: I.E.E. Views on the Post-War Position [and the Unanimity of Opinion in Favour of Legislative Control].—I.E.E. Radio Section. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, pp. 7–8.) For a "Monthly Commentary" note *see* p. 1.

1061. Progress in the Field of Interference Suppression.—H. Bette. (*Siemens Zeitschr.*, July/Sept. 1943, Vol. 23, p. 68 onwards.) A brief summary is given in *Bull. Assoc. Suisse des Élec.*, 26th July 1944, Vol. 35, No. 15, p. S.24.

1062. Radio-Noise Elimination in Military Aircraft.—G. Weinstein & others. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 793–795.)

A summary was dealt with in 460 of February. Among other conclusions, the work indicates that noise levels of 500–1000 μV, if specified for the electrical equipment, "would permit satisfactory levels of radio noise with a minimum filter weight." *Cf.* 1063, below.

1063. Requirements for Aircraft Electric Motors [including the Question of Radio-Noise Output and the Effect of Poor Seating of Brushes].—E. R. Siefkin. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 810–813.)

1064. Letter on "New Thoughts on Contrast Expansion" [3850 of 1944].—J. B. Rudkin: Roddam. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 27.)

1065. A Ham-Built Communications-Type Receiver: Constructing a 12-Tube General Coverage and Bandspread Superhet.—A. D. Mayo, Jr. (*QST*, April 1944, Vol. 28, No. 4, pp. 13–18 and 90..94.)

1066. Look before You Leap: a Survey of Power-Supply Systems encountered by American Troops serving Abroad [and the Behaviour of American-Manufactured Receivers for Domestic Consumption].—W. E. Bradley. (*QST*, July 1944, Vol. 28, No. 7, p. 64.)

AERIALS AND AERIAL SYSTEMS

1067. The Solution of Transmission-Line Problems by Use of the Circle Diagram of Impedance.—Willis Jackson & Huxley. (*See* 1031.)

1068. The Quadrant Aerial: an Omnidirectional Wide-Band Horizontal Aerial for Short Waves.—N. Wells. (*Journ. I.E.E.*, Part III, Dec. 1944, Vol. 91, No. 16, pp. 182–193.)

The investigation was prompted by the requirements of a scheme involving omnidirectional reception over a wide band of frequencies, and a multiplicity of comparatively low aerials: horizontal suspension was decided on because with such low aerials the signal/noise ratio is better in many cases (though worse as regards disturbance caused by rain) with horizontal polarisation than with vertical, and the vertical polar diagram is less influenced by ground conditions. Later, the design was applied to transmission, largely because it was independent of an earth system, but also because of the above greater freedom from ground absorption, which applies also to low transmitting aerials.

There are various types of horizontally disposed aerials giving an omnidirectional pattern (*e.g.* Brown's "turnstile" and Lindenblad's ellipsoidal variant), "but so far as the author is aware, none of these is designed for a sufficiently wide bandwidth to cover an octave, or more, in frequency. A study of this requirement led the author to the opinion that the inherent flatness, as regards change of frequency, of the ordinary figure-of-eight diagram due to a simple dipole, in combination with some expedient by means of which two such diagrams were superimposed in space quadrature, might best supply the solution . . ." Tests on 60 and 100 Mc/s, following preliminary analysis, showed that the "quadrant" aerial (a right-angled V-aerial with its limbs fed in antiphase at the apex) gave a substantially omnidirectional diagram when its limbs were of the order of $\lambda/2$ long, and that it was the only one of those tried out for which the change of shape of diagram with change of frequency was sufficiently slow: and it is simple in construction and easy to erect.

Such an aerial is investigated theoretically and experimentally in the paper. Including the limitation imposed by the permissible variation of terminal impedance, an over-all working limitation is arrived at of a 2 : 1 frequency band: for many classes of service where requirements are not stringent the octave may be exceeded. The question of grouping, when more than one aerial is required (*e.g.*, to cover a range of 2–20 Mc/s) is dealt with. Quadrants may be stacked to give greater control over the vertical polar diagram. The paper ends with a note on the quasi-omnidirectional property of the ordinary horizontal dipole, and the long-distance reception of the elliptically polarised signals from it.

1069. Directive Reception—an Answer to Post-War QRM? A Problem for the Experimenter.—C. T. Read. (*QST*, June 1944, Vol. 28, No. 6, pp. 9–10.)

A suggestion from the Asst. Secretary, A.R.R.L. "The possibilities of directional selectivity have hardly been touched . . . What amateur radio really needs is a simple, compact device that will permit directional reception on the lower frequencies of an order comparable to that obtained on the very-highs with an elaborate beam array . . . a device completely non-critical as to frequency but with a 'geographical band-width' of only 10 or 15 degrees of arc . . . The answer very probably will be found in a combination of well-known radio principles in

some new and unusual manner . . ." One or two possible lines of exploration are mentioned.

1070. Reciprocation Theorem of Electrodynamics for Transitory Processes.—J. N. Feld. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Dec. 1943, Vol. 41, No. 7, pp. 280–283: in English.)

"The reciprocation theorem of electrodynamics seems to have been thus far considered only for the case of harmonic oscillations." In the present work it is extended to include transient electromagnetic processes, arbitrarily varying with time. The Lorentz lemma div $[\vec{\mathfrak{E}}_1 \vec{\mathfrak{H}}_2] = \text{div}\,[\vec{\mathfrak{E}}_2 \vec{\mathfrak{H}}_1]$ is generalised to give eqn. 5 or the more applicable form of eqn. 5a, and this lemma, now including the case of arbitrary transitory processes, is used to establish the reciprocity theorem for two arbitrary aerials, the currents in which are assumed to flow only over their surfaces. The investigation of *finite* conductivity "would call for the introduction of spatial distribution of e.m.f. as well as some complication of the lemma 5a, without any modification of final results . . ."

VALVES AND THERMIONICS

1071. Energy Conversion in Electronic Devices [Discussion and Rational Classification of Fundamental Processes by which Steady Electromagnetic Oscillations can be produced in Such Devices: Treatment based on Principle of Conservation of Energy and the Property that "Whatever happens in a Volume can be Inferred from What happens at a Surface enclosing It": Current Modulation (Emission-Density, Deflection, Concentration, & Transit-Time or "Time-Compression" Modulations): Methods of producing Oscillating Electric Fields: etc.].—D. Gábor. (*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 128–141: Discussion pp. 141–145.)

A summary was referred to in 2181 of 1944. In a short final section on random electron motion (such as occurs in valves where electron paths cross one another), the writer remarks that his theory on the interaction of electrons in highly ionised gases (1933 Abstracts, p. 639, r-h column) gives good agreement with experiment, but requires corrections, further elaboration, and adaptation to the case of electrons in a vacuum. "It is perhaps not altogether a matter for regret that at least one corner of the theory of thermionic valves still retains a touch of mystery." Appendix 13.5 deals with "Energy Balance at Ultra-High Frequencies." Among other points in the Discussion, the writer "cannot agree with the revolutionary statement of Mr. Benham, that *any* transit-time damping means radiation from the valve. I have shown in Section 13.5 that only that the 'dipole' and higher terms of the transit power are associated with radiation."

1072. Deflected Electron Beams [Continuation of Correspondence dealt with in 3164, 3484, & 3865 of 1944, 57 of January, and 480 of February].—J. A. Jenkins: S. Rodda. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 73–74.)

1073. "Lighthouse" Tube [U.H.F. "Megatron," with Parallel-Plane Construction and Disc Seal].—General Electric. (*Sci. News Letter*, 19th Aug. 1944, Vol. 46, No. 8, p. 115.) "Greatly advances the frequencies and power available . . ."

1074. New Tube—R.C.A.-6J4 ["Button-Base" Triode for Frequencies up to about 500 Mc/s, with Amplification Factor 55 and 1200 Micromhos Transconductance: for Grounded-Grid Circuits, etc.].—R.C.A. (*QST*, July 1944, Vol. 28, No. 7, p. 58.)

1075. Midget Tubes for [Ultra-] High Frequencies [Pentodes Type 6AK5 & Type 6AJ5].—G. T. Ford. (*Bell Lab. Record*, Nov. 1944, Vol. 22, No. 15, pp. 605–608.)

1076. Investigations on Amplifier Pentodes with regard to the Estimation of Non-Linear Distortion.—H. Holzwarth. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 21, 1943, pp. 58–73.)

This is the paper referred to in 1593 of 1944. Author's summary:—"The accuracy with which the approximate formulae describe the discharge-law of pentodes is examined. The non-linear distortions are calculated, taking into account the voltage-dependence of the screen-grid 'durchgriff,' the current-sharing between screen grid and anode, and the electrostatic 'durchgriff' of anode on cathode. Comparison with measured values gives good agreement for pentodes with negligible electrostatic anode-'durchgriff' (h.f. pentodes) and confirms the possibility of a quantitative estimation of the distortions of output pentodes.

"A characteristic feature is the occurrence, even in conditions of great under-matching, of a null point, connected with a phase-reversal, in the non-linear-distortion factor ["klirr" factor] of the second harmonic (for $R_a \approx R_i/10$ in the case of amplifier pentodes): another is the large increase of the non-linear-distortion factor of the third harmonic with increase of external resistance. Finally, the causes and effects of the 'fine structure' of the valve characteristics [and the resulting "micro-klirr"-factors] are briefly discussed": they have been dealt with for diodes, triodes, and tetrodes by van der Pol & Weijers, 1934 Abstracts, pp. 563–564.

1077. Arrangement for the Suppression of Unwanted Retroactions in Electron-Multipliers used as High-Frequency Amplifiers [Use of Screening Cap which may contain a Screened Filter Circuit].—Anon. (*T.F.T.*, May 1944, Vol. 33, No. 5, p. 105.) D.R.P.744 209 of 29/7/1938: no name is given, but *cf.* Flechsig, 2573 of 1944.

1078. "To-&-Fro" Type of Electron-Multiplier with Two Secondary-Emission Electrodes facing Each Other [D.R.P. 744 210 of 15/3/1940].—Anon. (*T.F.T.*, May 1944, Vol. 33, No. 5, p. 105.)

Of the two main groups of multiplier, the "static" type has a number of s.e. electrodes at potentials constant in time and increasing from stage to stage: at each stage an incident electron is "multiplied" only once. In the "dynamic" type there are, as a rule, only two s.e. electrodes, and an alternating potential is used: each electron is thus "multi-

plied" several times. The invention comprises an intermediate type: the valve contains only two s.e. electrodes, subjected to one alternating potential, and of such a shape (" 2," " 3 " of Fig. 18: each of the two electrodes presents a series of concavities to the other) that the electrons, after each impact, are concentrated anew by the shape of the field, without the help of any magnetic field. The maximum current-density occurring is, as in the series-type multiplier, dependent only on the electrons proceeding from the last s.e. surface, so that no tendency to oscillation occurs.

1079. ECONOMY IN VALVE-TYPES IN GERMAN AIRBORNE EQUIPMENT.—(*See* beginning of Discussion on Edwards's Paper, 1083, below.)

1080. PROPERTIES AND APPLICATIONS OF NIOBIUM OR COLUMBIUM.—Ch. More. (*Génie Civil*, 15th April 1944, Vol. 121, No. 8, p. 66: summary, from *La Métallurgie*.)

1081. PROPERTIES OF SEALING GLASSES [Survey, with Special Attention to Chance Brothers' Data].—(*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, pp. 495–496.)

1082. PRACTICAL APPLICATIONS OF SIMPLE MATHEMATICS: Part II—PLATE AND SCREEN VOLTAGES.—E. M. Noll. (*QST*, June 1944, Vol. 28, No. 6, pp. 38–40.) For other parts of this series *see* 508 & 516 of February, and 1042, above.

DIRECTIONAL WIRELESS

1083. ENEMY AIRBORNE RADIO EQUIPMENT.—C. P. Edwards. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 44–63: Discussions pp. 63–66.) The full paper, summaries of which were referred to in 468 of 1944.

1084. AIRCRAFT D.F. EQUIPMENT: 1—SOME RECENT DEVELOPMENTS [including the " Switched Cardioid " Receiver with Electronic Switching (68 of January)].—C. B. Bovill. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, pp. 14–16.)

1085. THE GYROSYN COMPASS.—O. E. Esval. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 857–860.) From the Sperry Gyroscope Company.

ACOUSTICS AND AUDIO-FREQUENCIES

1086. THE EXTENSION OF THE HEAVISIDE EXPANSION THEOREM TO THE EQUATIONS OF ENGINEERING AND PHYSICS IN CURVILINEAR ORTHOGONAL COORDINATES.—Smith. (*See* 1025.)

1087. ELECTRO-ACOUSTIC QUADRIPOLES [Four-Terminal Networks: Microphones, Loudspeakers, etc.].—K. Braun. (*T.F.T.*, May 1944, Vol. 33, No. 5, pp. 85–95.)

Electro-acoustic quadripoles are divided into two classes, active and passive. In the first class, the input energy merely controls the energy (in another form) supplied by a local source: the arrangement is a relay or amplifier, and the only type considered here, the carbon microphone, is dealt with only briefly in a final section. The rest of the paper is concerned with the passive quadripole, which actually transforms the input energy into another form of energy and may therefore be rightly termed an " electro-acoustic converter." Such converters are classified as capacitive (conversion accomplished with the help of an electric field) or inductive (with the help of a magnetic field): the first class includes condenser and crystal types of microphone, telephone, and loudspeaker, while the second includes the electro-magnetic and moving-coil types. The quadripole equations and equivalent circuits, here derived, for the two classes of converter are very similar (*see* section 4): both classes may be regarded as " simple filters ".

For the capacitive converter the conversion factor is $A_k = (\partial Q_o/dx) \times 10^{3.5}$ (eqns. 15′ and 45) and for the inductive class $A_i = (\partial \psi_o/dx) \times 10^{-4.5}$ (pp. 90, 91), where Q_o and ψ_o are, respectively, the electric charge and the coil flux with whose help the energy conversion is accomplished. An ideal converter has the acoustic impedance matched to the electric: a determining factor for this matching is the ratio $(F_{\bar{a}}/A)^2$, where $F_{\bar{a}}$ is the equivalent surface of a piston diaphragm (only one-third of the surface of a typical plane diaphragm, which is deformed more or less spherically: p. 87, l–h column).

For a typical condenser microphone with $U_o = 100$ V, $C = 100 \times 10^{-12}$ F, and air-gap $x = 2 \times 10^{-3}$ cm, A_k comes out to about 0.015. For the same microphone worked at the maximum voltage without breakdown, 400 V, the value is about 0.06. For a crystal microphone the equation for the conversion factor becomes $A_k = (C/\delta) \times 10^{-3.5}$, where δ is the electric modulus. For a Rochelle-salt microphone with the same electrode and gap dimensions as the condenser microphone referred to above, this yields $A_k = 1.2 \times 10^3$, so that the conversion factor of a Rochelle-salt microphone is very much greater than that of a condenser microphone.

In the inductive class, a typical electro-magnetic telephone receiver has $A_i = 420$ by the equation, but actually this must be reduced to about 180 because of the saturation effect in the iron, not allowed for in eqn. 36a (for further consideration of this point *see* 792 [and 3431] of 1943). For a typical moving-coil converter $A_i = 218$, by eqn. 36b.

Section 5 deals with combinations of passive converters formed by the *mechanical* (not electrical) linking of two converters: such a combination may consist of two capacitive, two inductive, or one capacitive and one inductive converter. These cases are dealt with separately, and their possible applications are discussed. Section 6 on the carbon microphone, already referred to, includes such a combination, forming a " microphone amplifier ". The surprisingly high amplifying power of such a combination (2–3 nepers) is due to a reduction of the impulse damping at the acoustic output, usually large by the fact of the high mechanical impedance of the carbon granules.

1088. RECORDING AND REPRODUCTION OF SOUND.—I.E.E. Radio Section. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 96–97: summaries only.) For previous summaries *see* 1970 & 2610 of 1944. The disc *versus* film question was one of the subjects discussed.

1089. Letter on "New Thoughts on Contrast Expansion" [3850 of 1944].—J. B. Rudkin: Roddam. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 27.)

1090. The "Phase-Compressor": a Resistance–Capacity Output Circuit complementary to the "Phase-Splitter."—Parnum. (*See* 1041.)

1091. Cathode-Follower Output [Recommendation of Use of R.F. Pentode as A.F. Amplifier, particularly for Gramophone Reproduction].—C. George. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 28.)

1092. A Voltage Amplifier using a Pre-Saturation Diode as Load.—Durnford. (*See* 1039.)

1093. New Test Films check Performance of Sound-Motion Picture Equipment [for the Armed Forces].—(*Indust. Standardization* [New York], Nov. 1944, Vol. 15, No. 11, p. 238.)

1094. A Scattered System of Radiators in Sound Reproduction for Motion Pictures [Results of Comparison of System (3077 of 1943) with Ordinary Concentrated Reproduction].—L. D. Rosenberg & B. D. Tartatovsky. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th Nov. 1943, Vol. 41, No. 5, pp. 206–207: in English.)

1095. A Shipyard Public-Address System [for 20–30 Thousand Workers].—W. R. Aiken. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, pp. 402–404.)

1096. Sirens and Bells [including the Chrysler–Bell Super-Siren (Sound Output 42.2 kW: Calculated Range of Audibility 75 Miles) and a Chart of Intensities of Various Different Sounds].—J. O. Perrine. (*Scient. Monthly*, Feb. 1943, Vol. 56, No. 2, pp. 145–154.)

1097. A Variable Iron-Cored Inductor for Audio-Frequency Circuits [Type UTC-VI-C: embodying "a Simple, Positive Method of varying the Range 90% above & 50% below a Mean Value."]—United Transformer. (*QST*, June 1944, Vol. 28, No. 6, p. 57: paragraph only.)

1098. A New Method of Harmonic Analysis, *and* A New Mechanical Curve-Analyser.—Grützmacher: Kallenbach. (*See* 1251.)

1099. The Conquest of Distance by Wire Telephony: a Story of Transmission Development from the Early Days of Loading to the Wide Use of Thermionic Repeaters.—T. Shaw. (*Bell S. Tech. Journ.*, Oct. 1944, Vol. 23, No. 4, pp. 337–421.)

1100. Modern Submarine-Cable Telephony and the Use of Submerged Repeaters.—R. J. Halsey. (*Journ. I.E.E.*, Part III, Dec. 1944, Vol. 91, No. 16, pp. 218–232: Discussion pp. 232–236.)

The full paper, summaries of which were referred to in 2618 & 2812 of 1944. The discussion concentrates largely on the submerged repeater: other points include the possible increase of the number of circuits by the use of the Vocoder and by restricting the speech-band to 2000 c/s, the possibilities of loading in reducing cable attenuation, and the principles of the coaxial choke.

1101. Electrical Hearing Aids.—T. S. Littler. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 67–74: Discussion pp. 79–83.) The full paper, summaries of which were referred to in 1239 of 1944.

1102. A Basis for the Prediction of Performance of Hearing Aids.—C. M. R. Balbi. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 74–79: Discussion pp. 79–83.) The full paper, summaries of which were referred to in 1239 of 1944.

1103. An Aural Surface-Comparator [Adaptation of Stethoscope gives Handy & Sensitive Comparator].—S. M. Cox. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, p. 219.)

1104. "Sound Insulation and Acoustics" [Book Notice].—Building Research Board. (*Journ. of Scient. Instr.*, Jan. 1945, Vol. 22, No. 1, p. 19.)

1105. Propagation of Waves on the Surface of an Infinitely Long Circular Cylinder conceived as a Cut-Out Portion of an Infinitely Elastic Space.—Mindlin. (*See* 1026.)

1106. The Sonigage [Supersonic Thickness-Measuring Instrument primarily developed for Inspection of Hollow Steel Propeller Blades].—W. S. Erwin. (*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, pp. 487–488.)

1107. Flight in the Dark: a Study of Bats [Confirmation of the Auditory (Supersonic) Theory of Obstacle Avoidance].—R. Galambos. (*Scient. Monthly*, Feb. 1943, Vol. 56, No. 2, pp. 155–162.) *See* 1418 of 1941 and 3631 of 1942.

PHOTOTELEGRAPHY AND TELEVISION

1108. Frequency Modulation [and Plans for Post-War Television and U.H.F. Sound Broadcasting].—Bell. (*See* 1218.)

1109. A Survey of the Problem of Post-War Television.—B. J. Edwards. (*Journ. I.E.E.*, Part III, Dec. 1944, Vol. 91, No. 16, pp. 163–170: Discussions pp. 170–181.)

The full paper, a summary of which was dealt with in 2250 of 1944. In the course of his reply to the long discussions, the writer deals, among other points, with centimetric-wave links (and interference by aircraft) *versus* wave-guide transmission; frequency modulation (will not minimise echo effects); reduction of receiver cost; wide-band transmission and reception; the importance of sound transmission; the number of lines; time-modulated pulse transmission; economic factors (and the erroneous policy of "minimum change"); highly directive aerials to reduce multiple reflections (communal aerials?); projection lenses for larger pictures; and coaxial cables.

1110. Two-Way Television [without the Defect that Image Reception is Interrupted during Transmission: the Intensity-Modulated Reproducing Spot (never Completely Extinguished, even for Dark Parts of Image) is made to act as Scanning Spot for Transmission].—F. Schröter & others. (*Zeitschr. f. Fernmeldetech.*, 3rd April 1944, Vol. 25, No. 2, pp. 37–38.) D.R.P.735 598/21a1, applied for 15/1/39.

1111. Optical System enlarges Television Pictures [for Home Receivers].—I. G. Maloff & D. W. Epstein. (*Sci. News Letter*, 14th Oct. 1944, Vol. 46, No. 16, p. 248.)

1112. Colour transmitted by Wire: Photographs in Full Colour by Wire or Wireless in the Form of Three-Colour Separation Films.—Finch Telecommunications. (*Sci. News Letter*, 11th Nov. 1944, Vol. 46, No. 20, p. 308.)

MEASUREMENTS AND STANDARDS

1113. The Measurement of Balanced and Unbalanced Impedances at Frequencies near 500 Mc/s, and Its Application to the Determination of the Propagation Constants of Cables.—L. Essen. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 84–95.)

(i) Balanced measuring line: the parallel-wire system described by Chipman for frequencies around 300 Mc/s (1618 of 1939) was enclosed in a metal tube to reduce the variations produced by small movements of the observer: this also simplified the mechanical construction of the system. The highest frequency used was 740 Mc/s, which was the limit of the oscillator employed: the apparatus should be suitable for considerably higher frequencies, though it might then be advisable to make the conductor-spacing less than the 2 cm of the present line. (ii) Unbalanced measuring line, an air-spaced concentric line. In both types the line-length is varied by a movable bridge carrying a thermojunction unit.

Convenient working equations are developed, and results are given of measurements made to check the validity of the assumptions involved. Besides its application to the measurement of cable propagation constants (which is dealt with fully), the equipment has been used for impedance measurement on aerial systems. Some measurements on ceramic condensers and on carbon and metallised resistors are discussed.

1114. Experiments with Thermocouple Milliammeters at Very High Radio Frequencies [Performance of Commercial Instruments at 100 & 700 Mc/s: Special Collinearly-Mounted Instruments: Difficulties & Limitations].—G. F. Gainsborough. (*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 156–161: summary in *Nature*, 18th Nov. 1944, Vol. 154, No. 3916, pp. 646–647.)

"Errors dependent on current amplitude were found, and were shown to be due to the magnetic properties of the material used for the heater wires. The occurrence is confirmed of frequency-dependent errors, due to the method of constructing the ordinary instruments. Specially made instruments [self-heated thermocouples (Fig. 7) and milliammeters with collinear heater leads (Fig. 9)], though superior in respect of these errors, are likely to be of limited usefulness on account of the disturbance which is caused by the inclusion of any such device in a circuit carrying current at very high frequencies", say greater than 100–200 Mc/s. Nevertheless, thermocouple instruments of the types studied "will have wide applications as indicators of relative signal magnitude at the higher frequencies, provided they are used in fixed circuit conditions. They may also have an important use as milliwattmeters": though perhaps for these applications the collinearly-mounted instruments may not be superior to those of ordinary pattern.

1115. Basic Elements of a General Decimetric-Wave Measuring Technique.—L. Rohde. (*T.F.T.*, May 1944, Vol. 33, No. 5, pp. 95–105.)

From the Rohde & Schwarz laboratories. (i) Connecting leads and cables, junctions:—However convenient a stranded-wire flexible cable with metal-braid return may be, its disadvantages in high attenuation and unwanted couplings are so great (Fig. 1) that it has been replaced completely (at any rate for permanent connections) by the "tube wire" (concentric cable with solid dielectric) or the similar "oppanol cable": *see* 814 [and 1924] of 1944. A lead sheath is used as return: lead-covered cable made for the firm by the North German Cable Works, with a 0.8 mm thickness of lead, is quite flexible and very satisfactory: for cleanliness, the lead is coated with braid or a synthetic-resin sheath. The higher the frequency, the more important is the uniformity of characteristic impedance over the length of the conductor: bead-insulated cable shows too great a variation, but the oppanol solid-dielectric cable is satisfactory where variations below 5% are permissible. For the fairly rare cases when measurements must be accurate within less than 1%, it is best to use fixed tubes. Junctions are discussed: a satisfactory type has been evolved with a loose threaded cap as used in fire-hose junctions (Fig. 2): Meinke's paper (28 [and 2507] of 1944) is referred to here.

(ii) Change-over switches (Fig. 3). (iii) Calibrated line-sections, built up from short elements (Figs. 4–6), or consisting of different fixed sections combined with a multi-point switch (too extravagant in material for present application: Fig. 7). (iv) Standard-signal generators: a type (Fig. 8) for 170–800 Mc/s, giving 4 v to 70 ohms, with a "klirr" factor for the first harmonic of about 5%, so that between 800–1600 Mc/s a voltage of about 0.2 v can be obtained, which is often sufficient. With modern valves, higher frequencies can of course be generated even with triodes, but the tubular oscillatory systems suitable for these are not adapted to long ranges, and such signal generators are only made for special purposes, with limited frequency ranges: larger outputs are obtained by the use of magnetrons. Fig. 9 shows a 170–800 Mc/s generator for receiver testing, with a capacitive voltage-divider giving a signal of 1 μv to 30 mv: it provides either undamped waves or pulses of 1000 c/s frequency and a pulse-breath of 5×10^{-4}. The production of amplitude modulation for signal generators over a wide range is difficult if simultaneous frequency modulation is

to be kept low, but by suitable steps an a.m. of 80% can be obtained with a f.m. below 10^{-5}, over the range 170–800 Mc/s. Although the use of h.f. amplifying triodes, for example in the "grid-basis" connection (for this terminology and the connection in question *see* Kleen, 410 of 1944), may give better results and also higher outputs, such arrangements are only really applicable to small ranges of frequency.

(v) Voltmeters, standard voltages, and tuned voltmeters (including a tuned diode voltmeter, Fig. 12, for 300–2000 Mc/s, range 0·02 to 6 volts: provided with a de-coupling device and usable also as a resonance filter, a mixer stage, or a wavemeter accurate to about ±5%). (vi) Power measurement, from voltage and characteristic-impedance values: since voltages between 50 μV and 50 V can be measured by the methods described, powers between $3{\cdot}5 \times 10^{-11}$ and 35 W are easily dealt with: but above 1 W the load-carrying capacity of the terminating resistance has to be considered, and large surfaces and air cooling are brought in to help. Thermal and power measurements show good agreement even at these high frequencies—a confirmation of the correctness of voltage-measurement with diodes.

(vii) Impedance measurement: with a view to introducing a certain amount of system into a confused and difficult subject, a division may be made into "high resistance" and "low resistance" measurement: each requires a different technique, and the transition from one to the other is particularly troublesome. The first is often accomplished by resonance-frequency methods using tuned lines: deflection methods are possible, using standard resistances for comparison, but it is extremely difficult to make these high resistances independent of frequency. A better system is the admittance-measuring method dealt with in 1128 of 1940, which gives direct readings of the conductive and reactive components: in this method, a d.c. resistance is transformed into a h.f. resistance by means of a diode. Fig. 14 shows the equipment. Owing to the natural resistance of the diode, 1000 ohms is about the lowest value that can be measured at decimetric-wave frequencies: below this, a resonance transformer would be necessary to convert the low resistance to a high value. But a better plan is to use a test system with quite a low characteristic impedance, say 5 ohms, in the form perhaps of a $\lambda/4$ line, and to compare the object under test with a standard resistance: accurate characteristic impedances of the order of 70 ohms are easily obtained in this frequency-range. The writers are constructing an apparatus to measure resistances between 20 ohms and 20 kilohms, and reactive components 0.1–15 pF, by this method, for frequencies 100–800 Mc/s. But in many cases such impedances can better be measured by the compensation method using a "standard line" with known variable R, C, and L. Such a line (pp. 101–102, Fig. 15) is suitable for measuring values from $Z/5$ to $5Z$: it is made of a thick-walled aluminium tube with a slot for the moving tap, which is connected to a heterodyne voltmeter made up of a wide-band (±1 Mc/s) amplifier and an oscillator (300–800 Mc/s). The mixing process takes place in the oscillator directly: the sensitivity is continuously variable and lies between 0.5 and 50 mv. Mixing is satisfactory also at the harmonic frequencies, so that the indicating arrangement can be used up to 3000 Mc/s with a sensitivity around 50 mv. The technique is described.

(viii) High-, low-, and band-pass filters. (ix) Frequency measurement: Fig. 17 shows a small interference-type wavemeter (10 cm–10 m) with an accuracy within ±0·2%: Fig. 18 the lay-out diagram of a larger equipment for the same range (accurate to within ±0·002%) with a quartz oscillator. For still higher accuracy, distorting circuits are used to produce standard-frequency spectra from an accurate quartz oscillator or quartz clock: *see* 2636 of 1944. The standard test-line mentioned above in (vii) may also be used for quick frequency measurements if several frequencies are not present simultaneously and if sufficient voltage is available. (x) Measuring benches made up from the above components (Figs. 19, 20).

(xi) Field-strength measurement: Fig. 21 shows a portable equipment (with rotatable dipole aerial and a long lead to prevent interference by reflections from the operator) for fields from 10 μV/m to 1 V/m. Rotation of the dipole will give a certain amount of information as to the proportion of the direct and reflected components of the incident field, but for quantitative results a reflector of some kind is necessary. (xii) Just as the measured voltages derived from the dipole aerial serve to measure an unknown field, so a voltage supplied to the dipole will provide a known field at a definite distance. Such a standard-signal radiator may well have a parabolic reflector (Fränz's paper, 2898 of 1944, is here quoted): horn radiators are also useful, because of their high directivity, but care must be taken in the matching of the horn to the connecting cable.

1116. RESISTANCE AND CAPACITANCE MEASUREMENTS WITH THE VACUUM-TUBE VOLTMETER [Experience with the Instrument referred to in 863 of 1944].—A. D. Mayo, Jr. (*QST*, June 1944, Vol. 28, No. 6, pp. 31–33.)

1117. AN INEXPENSIVE IMPEDANCE BRIDGE.—A. Cosmas. (*QST*, July 1944, Vol. 28, No. 7, pp. 32–36 and 86, 88.)

1118. TESTING INSULATION OF LOW-VOLTAGE THIN-WALLED CABLE.—Anderson. (*See* 1317.)

1119. ELECTRONICS IN INSTRUMENTATION [for Measurement & Control].—Middel. (*See* 1312.)

1120. EQUIPMENT TO TEST MEASURING DEVICES [and Their Component Parts, for Quantity Production].—Princi. (*See* 1315.)

1121. THE TESTING OF RADIO EQUIPMENT AND COMPONENTS, AND THEIR TREATMENT TO MEET EXTREME CLIMATIC CONDITIONS.—I.E.E. Radio Section. (*Journ. I.E.E.*, Part III, June 1944, Vol. 91, No. 14, pp. 97–98: summaries only.) For other summaries *see* 2279 & 2801 of 1944: and *cf.* Coursey, 3545 of 1944.

1122. THE ORGANISATION OF EXPERIMENTAL RESEARCH [including Passages on Measurements in Telecommunication and on Statistical Quality Control and Statistical Methods in the Laboratory].—W. G. Rad-

ley. (*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, p. 485.) Conclusion of an abridgment of the address, a summary of which was referred to in 310 of January.

1123. MEASUREMENT OF H.F. MAGNETIC SUSCEPTIBILITY OF LIQUIDS AND SOLUTIONS BY THE HETERODYNE BEAT METHOD [New Way of Shielding the Liquid from the Electrostatic Influence of the Surrounding Inductor].—B. N. Singh & L. Prasad. (*Sci. & Culture* [Calcutta], Oct. 1944, Vol. 10, No. 4, pp. 172–173.)

1124. THE A_L MEASURING EQUIPMENT, A PERMEABILITY-TESTING APPARATUS FOR TRANSFORMER CORES. — M. Bidlingmaier. (*Zeitschr. f. Fernmeldetech.*, 3rd April 1944, Vol. 25, No. 2, pp. 39–40: long summary.) A short summary was referred to in 3237 of 1944.

1125. MASS, VOLUME, AND SURFACE RESISTIVITY [Letter on Editorials dealt with in 3233 of 1944 & Back Reference: the Special Convenience of Mass (or "Density") Resistivity in calculating Wire and Cable Resistances: etc.].—A. L. Meyers: G. W. O. H. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, p. 74.)

1126. B.S.I. SPECIFICATION IN BASIC [B.S.I. Experiment in translating Its Portland Cement Specification into Basic English: Some Specimen Extracts, with Comments].—British Standards Institution. (*Engineer*, 22nd Dec. 1944, Vol. 178, No. 4641, pp. 487–488.)

1127. STANDARDISED COMPONENTS [Letter, from Inter-Service Components Technical Committee, on "Properties of Radio Components" (532 of February)].—E. D. Whitehead: Roddam. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 28.) *See* also 1128, below.

1128. STANDARDISED COMPONENTS: II—PROPERTIES OF CAPACITORS [and the BS/RC Specifications].—T. Roddam. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, pp. 11–14.) For Part I *see* 877 of March.

1129. A NEW STANDARD OF WAVELENGTH [Preliminary Results (to 1941) of an Investigation of the Practicability of a Standard Wavelength in the Infra-Red Region: Its Advantages & Disadvantages: Usikov's Hollow-Cathode Source: Good Results].—L. B. Ponizovsky. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Nov. 1943, Vol. 41, No. 4, pp. 158–160: in English.)

1130. "UHR UND STROM" [Handbook of Electric Clocks: Book Review].—K. Scheibe & J. Stamm. (*E.T.Z.*, 23rd March 1944, Vol. 65, No. 11/12, p. 105.)

1131. HISTORIC FIRSTS: PIEZOELECTRIC OSCILLATOR. — A. M. Nicolson. (*Bell Lab. Record*, Nov. 1944, Vol. 22, No. 15, pp. 601–602.)

1132. TOURMALIN SCHISTS FROM HOLENARSIPUR, HASSAN DISTRICT, MYSORE STATE.—C. S. Pichamuthu. (*Current Science* [Bangalore], Nov. 1944, Vol. 13, No. 11, pp. 279–280.)

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1133. LOW-FREQUENCY CATHODE-RAY OSCILLOGRAPH [extending the L.F. Range to below 1 c/s].—Mullard Company. (*Engineer*, 15th Dec. 1944, Vol. 178, No. 4640, pp. 479–480.)

1134. COLD-CATHODE TUBE EMITS 50 000-VOLT BEAM [New Oscillograph with Photoelectric Control of Exposure of Film, for One Revolution only, on Drum with Speed variable up to 7000 r.p.m.].—Westinghouse. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, p. 422: photograph and caption only.)

1135. "ELECTRON OPTICS" [Book Review].—Hatschek. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 260–261.) A previous review was referred to in 2673 of 1944. The present reviewer stresses some serious defects.

1136. DEFLECTED ELECTRON BEAMS [Continuation of Correspondence].—Jenkins: Rodda. (*See* 1072.)

1137. ELECTRONIC MICROSCOPY [Illustrated Survey].—Zworykin & Hillier. (*Scient. Monthly*, Sept. 1944, Vol. 59, No. 3, pp. 165–179.) Including the scanning-type and desk-type microscopes, the microanalyser, etc.

1138. IMPROVED ELECTRON-MICROSCOPIC STRUCTURE INVESTIGATION OF METALS [by the Lacquer Replica Process: Separation of Film from the Metal Surface by Acid (and Consequent Effect on Surface) avoided by a Cathodic Process].—Duffek & Mahl. (*Zeitschr. V.D.I.*, 28th Nov. 1942, Vol. 86, No. 47/48, p. 726: summary only.)

1139. MICROSCOPY WITH LIGHT, ELECTRONS, AND X-RAYS [Survey].—Preston. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, pp. 205–213.)

1140. PHASE-DIFFERENCE MICROSCOPY [Extension of General Theory & Optical Design: Applications to Examination of Bacteria, etc., and (in Industry) of Transparent Plastics, Homogenised Milk, etc.].—Richards. (*Nature*, 25th Nov. 1944, Vol. 154, No. 3917, p. 672.) *Cf.* 1741 of 1941; 798 & 2066 of 1942; and 144 of 1943.

1141. RESOLUTION LIMIT OF PHOTOGRAPHIC OPTICAL INSTRUMENTS.—Moroz. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Dec. 1943, Vol. 41, No. 8, pp. 326–328: in English.)

1142. RESOLUTION OF LARGE OBJECTS IN CONTACT BY AN OPTICAL SYSTEM.—Halpern. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Jan. 1944, Vol. 42, No. 2, pp. 57–61: in English.)

1143. CORRESPONDENCE ON "LINEARITY CIRCUITS" [for Time Bases: 2677 of 1944].—Hamburger: Clarke. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 72–73.) With the true Bedford circuit true linearity is theoretically and, for all likely purposes, practically possible. Clarke's forecast of the possible future use of non-linear resistances seems to be confirmed by the recent appearance of several patents on the use of "thermistors" [*see* for example 2788 of 1942, and *cf.* 581 of 1944] in time-base circuits.

1144. AN AUTOMATIC STABILISER, WITH SMALL TIME CONSTANT, FOR A.C. MAINS VOLTAGES [Stabilisation, for Load of about 10 Watts, within 0.05% when Supply varies from 104 to 108 Volts: Time Constant 0.1 Second or Less: using Two Tranformers and a 6L6 Pentode connected as Triode].—Lecolazet. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 527–528.)

1145. SCREENS WITH UNEVEN SURFACES [Analysis (with Experimental Confirmation) of the Brightness of a Surface covered with Cone-like Depressions, (i) illuminated with Visible Light, (ii) Self-Luminescent, and (iii) Phosphor luminescent under Action of "Red" Light: Mean Brightness may be Many Times that of a Plane Screen].—Antonov-Romanovsky. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Nov. 1943, Vol. 41, No. 5, pp. 202–205: in English.)

1146. DEPOLARISATION OF PHOTOLUMINESCENCE OF DECAYING. — Wawilow. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th March 1944, Vol. 42, No. 8, pp. 331–335: in English.)

"In accordance with the generally adopted views on the process of photoluminescence in liquid and solid media, one may in certain cases expect a gradual depolarisation to take place on the decaying of the emission. This phenomenon does not appear to have engaged anyone's attention so far, in spite of its considerable importance as a new means of determining the basic features of the processes developing in the medium. To instance this may serve the 'decay polarisation' of the emission of certain uranyl glasses, discovered by A. N. Sevchenko (1147, below). Behind the depolarisation observed on decaying one should surmise the operation of two principal causes: (i) the Brownian rotation of excited molecules, if the viscosity of the medium is such as to permit an appreciable rotation to be made during the mean life-time of the excited state, and (ii) the resonance between the excited and unexcited molecules. To these two causes primarily responsible for depolarisation may add a third, of rather incidental character, connected with overlapping of absorption and emission spectra . . . " The present analysis is based on the two principal factors only.

1147. POLARISATION OF PHOTOLUMINESCENCE IN URANYL GLASSES.—Sevchenko. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th March 1944, Vol. 42, No. 8, pp. 336–340: in English.)

Referred to in 1146, above. "Wawilow (ref. '9') has shown theoretically that the polarisation of photoluminescence is a most sensitive and convenient method for determining the nature of elementary radiators . . . In this way I have established the dipole nature of the radiation of uranyl glasses . . ." Regarding the decrease of polarisation as the luminescence decays, in the case under consideration the viscosity of the glasses is much too high for the Brownian movement to be the factor: the most probable cause is the migration of energy due to quantum-mechanical resonance between molecules.

1148. ON THE POLARISED FLUORESCENCE OF DYE-STUFFS IN SOLUTION.—Choudhuri. (*Indian Journ. of Phys.*, April 1944, Vol. 18, No. 2, pp. 74–83.) Systematic measurements undertaken in view of the contradictory results obtained by various workers.

1149. POLARISATION OF FLUORESCENCE AND ANISOTROPY OF MOLECULES OF ORGANIC DYE-STUFFS.—Feofilov. (*Journ. of Phys.* [of USSR], No. 2, Vol. 7, 1943, pp. 68–79: in English.)

1150. FLUORESCENCE OF NAPHTHALENE CRYSTALS [Spectrum similar to Resonance Spectrum of Gases: Four Electron Transitions found: etc.]—Obreimov & Shabaldas. (*Journ. of Phys.* [of USSR], No. 4, Vol. 7, 1943, pp. 168–178: in English.)

1151. PROPERTIES OF SEALING GLASSES [Survey, with Special Attention to Chance Brothers' Data].—(*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, pp. 495–496.)

1152. INSTRUMENT FOR THE MEASUREMENT OF PUMPING SPEED OF HIGH-SPEED VACUUM PUMPS.—Alexander. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, pp. 216–218.) From the Vapco laboratories.

1153. MEASUREMENT OF HIGH VACUA [Survey of Gauges used for Pressures measured in Microns of Mercury, and Their Application to Automatic Control of Manufacturing Processes].—Zielinski. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 112–115.)

1154. PRECISION LOW-PRESSURE GAUGE [possessing "a Number of Novel Features"].—Wallace & Tiernan Products. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 273.) The pressure-sensitive element consists of a number of beryllium-copper capsules in series.

1155. THE RADIUM INSTITUTE CYCLOTRON: I—THE ARC TYPE OF ION SOURCE.—Alkhazov & others. (*Journ. of Phys.* [of USSR], No. 1, Vol. 8, 1944, pp. 56–61: in English.)

1156. A MODIFIED ARC ION SOURCE FILAMENT FOR THE CYCLOTRON [Modification of Tungsten Filament gives Increased Life and Proper Striking of Arc].—Boyd. (*Review Scient. Instr.*, Sept. 1944, Vol. 15, No. 9, p. 230.)

1157. THE INITIATION OF LONG ELECTRICAL DISCHARGES [and the Glow/Arc Transition Theory].—Bruce. (*See* 1029.)

1158. "Der elektrische Strom in Hochvakuum und in Gasen" [Book Review].—Dosse & Mierdel. (*Zeitschr. f. Fernmeldetech.*, 3rd April 1944, Vol. 25, No. 2, p. 40.) In Fassbender's series "Physik und Technik der Gegenwart".

1159. Pentode Ignitrons for Electronic Power Converters.—Steiner, Zehner, & Zuvers. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, Transactions pp. 693–697.)

1160. Arc Rectifier of Alternating Current.—Borovick. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Feb. 1944, Vol. 42, No. 4, p. 174: in English.)

The arc takes place in air between iron electrodes whose cross-section can be so chosen that the rectified current may be several tens of amperes. A triode valve, with its grid joined to its filament, is involved: "one phase of the alternating current is delayed by this tube. The arc . . . begins to burn in time with these interruptions, whereby the rectification of the current is brought about." Rectification is complete, the supplementary expenditure of energy is very small: the system has certain advantages over the mercury rectifier, though it is less economical because of the greater voltage-drop at the arc in air.

1161. Rectifiers with Mechanically Moved Contacts [Summary of Recent German Patents].—Strobl. (*Elektrot. u. Masch: bau*, 23rd July 1943, Vol. 61, No. 29/30, pp. 358–360.)

1162. Testing Selenium Rectifier Cells.—Schwanhausser. (*See* 1319.)

1163. On Our Knowledge of the Commercial Selenium Rectifier.—Selényi. (*Elektrot. u. Masch:bau*, 3rd Sept. 1943, Vol. 61, No. 35/36, pp. 432–434: long summary, from *Elektrotechnika*.)

1164. The Copper-Oxide Rectifier in Electrochemical Work [and Some Types of "Rectox" Apparatus & Their Uses].—Smith. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, Transactions pp. 739–744.)

1165. Aircraft Storage Battery Design [Requirements: Departures from Sound Practice: Suggestions for Correction].—Rupp. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 773–777.)

1166. Tap Water and Accumulators.—"Diallist." (*Wireless World*, Jan. 1945, Vol. 51, No. 1, pp. 30–31.)

1167. Restoring Dry Cells: a Method of Multiplying Normal Battery Life.—Eubank. (*QST*, June 1944, Vol. 28, No. 6, pp. 11–15.)

"By correct employment of this system, useful service life may be increased from 10 to 25 times at negligible cost." *Cf.* Kennedy, 1308 of 1944, and back reference.

1168. On the Theory and Practice of the Universal Motor.—Bolz. (*Elektrot. u. Masch:bau*, 28th April 1944, Vol. 62, No. 17/18, pp. 197–207.)

1169. Rating of Electric Equipment under Intermittent Load [and the Meaning & Use of the "Duty Factor," Product of a "Hit" Factor & a "Group" Factor].—Zucker. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 778–783.) Primarily in connection with resistance welding.

1170. Altitude Rating of Electric Apparatus: *also* The Testing of Brushes for Life and Performance under Various Altitude Conditions: *and* New Test Chambers for Aircraft Electric Apparatus.—Lebenbaum: Herman: Summers & Settle. (*Elec. Engineering*, Aug. 1944, Vol. 63, No. 8, p. 313: summaries only.)

1171. Brief Survey of Power-Supply Developments on British Aircraft [including Radio & Radio-Location Power Supplies].—Carter. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 806–807.)

1172. High-Altitude Brush Problems.—Ramadanoff & Glass. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 825–830.)

1173. Standardised Components: II—Properties of Capacitors.—Roddam. (*See* 1128.)

1174. On the Thermal Expansion of Insulating Paper [affecting, among Other Things, the Capacitance of Paper Condensers: Lack of Previous Investigation: Measurements of Coefficients of Expansion: etc.].—Wallraff. (*Elektrot. u. Masch:bau*, 28th April 1944, Vol. 62, No. 17/18, p. 220: summary, from *Arch f. Elektrot.*, Vol. 37, 1943.)

1175. On the Dielectric Loss and Curve Shape of the Current in Laminated Insulating Materials under High A.C. Fields of 50 c/s.—Liebscher. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 21, 1943, pp. 74–108.)

Laminated dielectrics, such as paper/oil (particularly when the oil has a high ionic conductivity) show a constant loss-current component i_v due to ionic movement in the liquid (curve "c" of Fig. 1). But if measurement gives an i_v constant with increasing voltage, nevertheless this increasing voltage must speed up the ion velocity, so that the ions will traverse their paths in the dielectric in ever shorter times: hence at a high enough a.c. voltage an impoverishment in ions must occur in the course of a half-cycle, since the number of available ions is limited. These considerations lead to the conclusion that the current in the dielectric can no longer be sinusoidal, and make it desirable to measure its wave form. An oscillographic method of doing this was given by Gemant (Abstracts, 1930, p. 172, r-h column, and 1931, p. 164, r-h column) but so far as the writer is aware has never been developed. The method is described and the present writer's results with it are given in full. *See* also 3979 of 1944.

1176. "Kunststoffe im technischen Korrosionsschutz" [Handbook for Vinidur & Oppanol: Book Review].—Krannich

(Edited by). (*Zeitschr. V.D.I.*, 18th March 1944, Vol. 88, No. 11/12, p. 164.)

1177. THE INSULATING POWER OF SYNTHETIC MATERIALS [under the Influence of Moisture].—Vieweg & Gottwald. (*E.T.Z.*, 23rd March 1944, Vol. 65, No. 11/12, p. 100: summary, from *Kunststoffe*, 1943.)

Amber, which has such excellent insulating powers (especially for electrostatic purposes), loses them in the presence of a high degree of humidity; but it becomes almost free from this defect if its surface is coated with a thin film of oil. The writers have investigated whether synthetic materials (trolitul, plexiglass, and vinidur) show the same effects. Particulars of the tests are given in the summary: a d.c. voltage of 2000–3000 V was used.

The surface resistance of clean polished trolitul decreased rapidly with increasing humidity. A coating of lubricating oil (clock oil) did nothing to help, but paraffin oil and paraffin wax gave a good protecting action. Plexiglass showed less dependence on moisture, and consequently was less affected by the paraffin film. An untreated surface of vinidur showed the smallest dependence on humidity of all three, but gave the unexpected result that both paraffin oil and lubricating oil produced such a big drop in surface resistance with increasing humidity that the discharge time could not be measured. Solid paraffin produced no deterioration of the good insulating properties. It is thought that the oil, penetrating into the vinidur, must have some chemical reaction with the chlorine of the polyvinyl chloride: it is important, therefore, that in the workshop vinidur parts should not be allowed to remain long in contact with oil and should be washed with water after the finishing process. For previous work *see* 2024 of 1944 and back reference.

1178. PLASTIC DEVELOPMENTS ["Fosterite", a Moisture-Proof Plastic (and the Defects of Previous Methods of proofing Windings, etc.): "Preformed Plastic"].—Westinghouse. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 212.) *See* also 3985/6 of 1944.

1179. THE TESTING OF RADIO EQUIPMENT AND COMPONENTS, AND THEIR TREATMENT TO MEET EXTREME CLIMATIC CONDITIONS.—I.E.E. Radio Section. (*See* 1121.)

1180. SYNTHETIC RUBBERS AND PLASTICS: VIII —ULTRA-HIGH-FREQUENCY DIELECTRICS [Polythene, Polyisobutylene, & Polystyrene].—Scarfe. (*Distribution of Elec.*, Jan. 1945, Vol. 17, No. 157, pp. 358–361.) For German work on solid-dielectric u.h.f. cables *see* Rohde, 814 of 1944.

1181. POLYTHENE DATA.—du Pont de Nemours. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, pp. 212–213.) *See* also 3988 of 1944 and back reference; also 219 of January & 570 of February.

1182. PLASTICS [Synthetic Resin & Micarta 444 (3986 of 1944)].—Westinghouse. (*Review Scient. Instr.*, Sept. 1944, Vol. 15, No. 9, pp. 232–233.)

1183. PLASTICS: A BRIEF REVIEW OF THEIR PHYSICAL AND ELECTRICAL PROPERTIES [with Many Tables of Data].—Warner. (*Elec. Communication*, No. 1, Vol. 22, 1944, pp. 70–86.)

1184. "PLASTICS FOR PRODUCTION" [Book Review].—Smith. (*Engineering*, 3rd Nov. 1944, Vol. 158, No. 4112, p. 343.)

1185. MODERN PROBLEMS OF MATERIALS [Aluminium as a Substitute for Copper: Glass Fibres: Organic Fibres: Regeneration of Insulating Oils & Rubber: Synthetic Resins].—Stäger. (*Bull. Assoc. Suisse des Elec.*, 12th July 1944, Vol. 35, No. 14, pp. 364–380: in German.) Survey, based on information from various big Swiss firms.

1186. "FORTISAN" FIBRE.—British Celanese. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 357: paragraph only.) *See* also 568 of February.

1187. "CELLULOSE AND CELLULOSE DERIVATIVES" [Book Review].—Ott (Edited by). (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, p. 720.) An Interscience publication, by a staff of specialists.

1188. "VARNISH CONSTITUENTS" [Book Review].—Chatfield. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 412–413.)

1189. THE DIELECTRIC PROPERTIES OF THE CONSTITUENTS OF LAC: *also* OF DIFFERENT MIXTURES OF HARD AND SOFT LAC RESIN: *and* OF MODIFIED LAC.—Bhattacharya. (*Indian Journ. of Phys.*, April 1944, Vol. 18, No. 2, pp. 97–115: pp. 116–125: pp. 126–134.) Further development of the work dealt with in 213 of January: *see* also 192 & 2852 of 1941 and 202 & 889 of 1943.

1190. A TRANSPARENT FLEXIBLE SYNTHETIC MATERIAL FOR SPLASH CURTAINS, ETC: "COMPAR".—Resistoflex Corporation. (*Scient. American*, Oct. 1944, Vol. 171, No. 4, pp. 176–177.)

1191. CONDUCTING RUBBER [New Developments].—Cohan & Steinberg. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, p. 728: summary only.)

1192. MEASUREMENT OF THE DIELECTRIC CONSTANT OF GASEOUS CO_2 TO 10 ATMOSPHERES.—van Itterbeek & Speepen. (*Physica*, Jan. 1944, Vol. 11, p. 43 onwards.)

1193. HIGH-VOLTAGE COMPRESSED-GAS POWER TRANSFORMERS.—Hobart. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 690–692.) Following on the work dealt with in 210 of January. The possible use of sulphur dioxide is among the points considered.

1194. THE HERTZIAN SPECTRUM OF GLYCERIN [Dispersion Curves for Wavelengths 3 cm to 10 m, at 20° & 40°].—Girard & Abadie. (*Comptes Rendus* [Paris], 4th/26th Oct. 1943, Vol. 217, No. 14/17, pp. 317–319.) *See* also 3916 of 1944.

1195. Mechanism of Dielectric Heating: Modern Theories and Their Application to Practical Problems.—Hartshorn. (*See* 1332.)

1196. Application of Statistics to Dielectrics.—Summers & Ross. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, pp. 405–407.) A summary was dealt with in 3622 of 1944.

1197. "Technische Physik der Werkstoffe" [Book Review].—Zwikker. (*Zeitschr. f. tech. Phys.*, Jan. 1943, Vol. 24, No. 1, pp. 18–19.)

1198. Copper–Beryllium–Cobalt Alloy [Properties & Uses].—(*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, p. 488.)

Note on a recent demonstration. In the radio industry the alloy is used for valve clips and for intricate springs formed when the metal is soft and then hardened by heat treatment. It is also used for contacts, etc.

1199. Properties and Applications of Niobium or Columbium.—More. (*Génie Civil*, 15th April 1944, Vol. 121, No. 8, p. 66: summary, from *La Métallurgie*.)

1200. Electron-Diffraction Patterns of Copper–Gold Alloys [in connection with the Development, by Heat Treatment, of Contact Materials, etc.].—Haworth. (*Bell Lab. Record*, Nov. 1944, Vol. 22, No. 15, pp. 596–600.)

1201. Bibliography of Relay Literature, 1940 to 1943.—A.I.E.E. Subcommittee. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, Transactions pp. 705–709.)

1202. The Elementary Skin-Effect.—Arkadiev. (*See* 1046.)

1203. Apparatus for the Investigation of Magnetic Materials, giving Simultaneous Viewing of Major and Minor Hysteresis Loops.—Toomim & Wildfeuer. (In paper dealt with in 832 of March.)

1204. A Variable Iron-Cored Inductor for Audio-Frequency Circuits. — United Transformer. (*See* 1097.)

1205. Interlamination Resistance [and the Derivation of a Simple Equation giving the Minimum Resistance for Any Degree of Permissible Stray Loss].—Barton. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 670–672.)

1206. Recent Development of Permanent Magnets of Iron–Nickel–Aluminium Alloys with and without the Addition of Copper, Cobalt, and Titanium: Their Shapes and Applications.—Zumbusch. (*Elektrot. u. Masch:bau*, 18th Dec. 1942, Vol. 60, No. 51/52, pp. 533–547.)

1207. Efficiency and Economy of Moulded-Powder Permanent Magnets with Synthetic Resin as Binding Material [Baermann's "Tromalit" & Its Applications: Some Typical Forms, and Comparison with Cast Magnets as regards Efficiency, Economy in Material, & Manufacturing Cost.]—Dehler: Baermann. (*E.T.Z.*, 23rd March 1944, Vol. 65, No. 11/12, pp. 93–95.) For previous work *see* 3537 of 1941 and 1741 of 1943. The idea that such moulded magnets involve a high loss of energy is refuted.

1208. Some Aspects of Powder Metallurgy [Survey, with 66 Literature References].—Schumacher & Souden. (*Bell S. Tech. Journ.*, Oct. 1944, Vol. 23, No. 4, pp. 422–457.)

1209. Production of Uniform Magnetic Field by a Pair of Magnetic Dipoles.—Crittenden & McDaniel. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 270.)

1210. Probability Method applied to the Analysis of Recrystallisation Data.—Dunn. (*Phys. Review*, 1st/15th Oct. 1944, Vol. 66, No. 7/8, pp. 215–220.)

1211. Metals and Metal Finishing in the Radio Industry [Summary of Discussion Meeting].—I.E.E. Radio Section. (*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 161–162.)

Previous summaries were referred to in 2742 of 1944. "The discussion revealed the intense interest that is being taken in all forms of finishing in the radio industry, and the considerable promise which exists of striking developments in the near future."

1212. Surface Finishes [Set of Stainless Steel Blocks giving Aid in specifying Surface Roughness, and allowing Correlation between Engineering, Production, & Inspection].—University Machine Company. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 273–274.)

1213. Low-Voltage Soldering Iron.—"Diallist." (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 30.) *See* also Stephenson, p. 28 (and 2049 of 1944).

1214. Six-Volt Soldering Irons [including One for Very Light Work using the Projecting "Lead" of a Metallic Propelling Pencil as One Electrode]. — Hewett: La Croix. (*QST*, June 1944, Vol. 28, No. 6, pp. 59 and 82.)

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1215. High-Speed Recording of Radio-Telegraph Signals.—Armstrong & Smale. (*See* 1058.)

1216. Enemy Airborne Radio Equipment.—Edwards. (*See* 1083.)

1217. Electronics in Transportation [Radio & Radar Applications in the Post-War World].—(*Scient. American*, Oct. 1944, Vol. 171, No. 4, pp. 160–162.)

Thus "the Great Lakes shippers are using radio and exploring radar as protection against the peculiar perils that beset their vessels . . ."

1218. Frequency Modulation [and Plans for Post-War Television & U.H.F. Sound Broadcasting: the Misconception that F.M. gives No Protection against Powerful Ignition or Similar Pulses: Summarised Properties of F.M. in This Respect, as Basis for Comparison with (*e.g.*) Wide-Band A.M. with A.F. Limiting].—Bell. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, p. 73.)

1219. Milwaukee's Radio City [Modern Combination Studio & Office Building feeding F.M. & A.M. Transmitters].—Milwaukee Journal. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 94–99.)

1220. Colonial Broadcasting: "Long-Short" Waves for covering Tropical Areas?—(*Wireless World*, Jan. 1945, Vol. 51, No. 1, pp. 9–10.) For a "Monthly Commentary" note ("A Brand-New Industry") *see* p. 1.

1221. The Alaska Communication System.—Fowler. (*QST*, April 1944, Vol. 28, No. 4, pp. 9–12.)

1222. A WERS Control-Station Receiver.—Heubner. (*See* 1056.)

1223. A Novel 112 Mc/s WERS Transceiver [including Device for Changing the Aerial Coupling by the Send/Receive Switch, to avoid a Creep of Frequency during a Series of Two-&-Fro Transmissions].—Mitchell. (*QST*, April 1944, Vol. 28, No. 4, pp. 36–38.) Another unusual feature is the use of a half-wave element instead of a quarter-wave, and the provision of a close-spaced parasitic element as reflector.

1224. A Self-Contained Handie-Talkie: a Compact Light-Weight WERS Unit operating from Dry Batteries.—Haist. (*QST*, June 1944, Vol. 28, No. 6, pp. 28–29.)

1225. Correspondence on the Amateur "High" *versus* "Low" Power Argument [*see* also 3636 of 1944].—(*QST*, April 1944, Vol. 28, No. 4, pp. 54–59.)

GENERAL PHYSICAL ARTICLES

1226. Static Isotropic Solutions of Einstein's Field Equations.—Wyman. (*Phys. Review*, 1st/15th Nov. 1944, Vol. 66, No. 9/10, pp. 267–274.)

"Our method of treating the non-linear differential equations involved seems to be quite powerful, and it is hoped that the method will serve as a guide to those seeking other types of solutions of the field equations."

1227. Non-Conservative Fundamental Particles [of Interest in view, for instance, of the Still Open Possibility of the Non-Existence of the Neutrino].—Proca. (*Nature*, 25th Nov. 1944, Vol. 154, No. 3917, p. 674.)

"The striking fact about the above equation is that it follows quite naturally from a straightforward application of restricted relativity to the problem of the electron. This does not mean that it necessarily fits the physical reality, but seems to point towards the fact that its study might be worth while." *Cf.* 2766 of 1944.

1228. On the Stability of the Electron [and the Forces between the Infinitely Small Charges constituting the Total Charge].—Brylinski. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 481–483.)

Leading, among other things, to the conception of a variability in volume of the electron and an explanation of its dematerialisation: "any appreciable (not necessarily considerable) diminution of the speed of rotation makes the electrostatic forces of repulsion predominate over the attractive forces of cohesion, so that the component elements of the electron are dispersed in space and the electron is destroyed."

1229. Unification of the Theories of Photon and Meson.—Born. (*Nature*, 16th Dec. 1944, Vol. 154, No. 3920, pp. 764–765.)

1230. Problems of Modern Physics.—Frenkel. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 417–421.) Translated from the Russian. The continuation was referred to in 241 of January.

1231. Inertia of the Carrier of Electricity in Copper and Aluminium [m/e Ratio measured accurately by Use of Coil supported as Torsional Pendulum].—Kettering & Scott. (*Phys. Review*, 1st/15th Nov. 1944, Vol. 66, No. 9/10, pp. 257–267.) Showing conclusively that the carrier of the electric current has the same mass-to-charge ratio as that of the electron.

1232. On the Range of Values of Physical Quantities.—Barnóthy. (*Zeitschr. f. Phys.*, 12th Jan. 1943, Vol. 120, No. 3/4, pp. 148–164.)

"The range of values of all measurable physical quantities is constant and bears a simple mathematical relation to a dimensionless number which, as the basic number of value-range, lines up with the constants c, f, and time acceleration i as the fourth fundamental natural constant and has the value $\gamma \approx 4{\cdot}5 \times 10^{40}$."

1233. On the Dimensions of Physical Magnitudes (Fifth Paper).—Dingle. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 616–618.) Reply to Wilson's letter: *see* 252 of January.

1234. Electomotive Force and Potential Difference [including the Case of a Wave Guide or Transmission Line: Editorial].—G.W.O.H. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 53–55.)

1235. Magnetic Ions [Attempt to verify Ehrenhaft's Conclusions: Negative Result: Suggested Explanation of Ehrenhaft's Results], *and* Test for Change of Pole Strength of Permanent Magnet [prompted by Ehrenhaft's Report: Negative Result].—Hopper: Goldman: Ehrenhaft. (*Phys. Review*, 1st/15th Aug. 1944, Vol. 66, No. 3/4, pp. 93–94: p. 94.)

1236. The Magnetic Current [Criticism of Kendall's Letter (1718 of 1944) and Survey of the Present Writer's Observations].—Ehrenhaft: Kendall. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 426–427.)

MISCELLANEOUS

1237. The Extension of the Heaviside Expansion Theorem to the Equations of Engineering and Physics in Curvilinear Orthogonal Coordinates.—Smith. (*See* 1025.)

1238. On the Integral Equations of Continuous Dynamical Systems.—Ingram. (*Proc. Nat. Acad. Sci.*, Nov. 1944, Vol. 30, No. 11, pp. 370–376.) Further development of the work dealt with in 4480 of 1940: for other recent work *see* 435 of February.

1239. Some Devices for the Solution of Large Sets of Simultaneous Linear Equations: with an Appendix on the Reciprocation of Partitioned Matrices.—Duncan. (*Phil. Mag.*, Oct. 1944, Vol. 35, No. 249, pp. 660–670.)

1240. An Iteration Method for the Graphical Solution of [the Simultaneous Differential Equations of] Regulation Problems [Governing of Steam Turbines, etc.].—Martin. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 21, 1943, pp. 239–245.)

1241. On Operational Solutions of Systems of Linear Differential Equations with Constant Coefficients [as encountered in Problems of Automatic Control].—Bulgakov. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Nov. 1943, Vol. 41, No. 6, pp. 234–238: in English.) *See* also 4029 of 1944.

1242. On Two Fundamental Groups of Singular Points [for the Differential Equation determining the Conditions of Existence of Periodic & Aperiodic Vibrations].—Koukless. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 29th Feb. 1944, Vol. 42, No. 6, pp. 253–255: in French.)

1243. On the Stability of Periodic Movements [Supplement to Lyapounoff's Fundamental Theorems: Sufficient Conditions for Stability or Instability of Periodic Solutions for Mechanical Systems with Several Degrees of Freedom].—Nougmanova. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Feb. 1944, Vol. 42, No. 5, pp. 202–204: in French.)

1244. Introduction to the Theory and Application of Hyperbolic Functions.—Hameister. (*Zeitschr. f. Fernmeldetech.*, 16th Dec. 1942, Vol. 23, No. 12, pp. 177–182.)

1245. Correspondence on Comrie's "Recent Progress in Scientific Computing" [275 of January].—Mallock, Aruja, Comrie. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, pp. 218–219.) Including a plea for a glare-free surface-finish for the dials of calculating machines and other instruments.

1246. On Invariant Theory under Restricted Groups [Extension of 1723 of 1944].—Littlewood. (*Phil. Trans. of Roy. Soc.*, Series A, 25th Nov. 1944, Vol. 239, No. 809, pp. 387–417).

1247. Significant Figures of Numbers in Statistical Tables, *and* Distribution of Significant Figures.—Goudsmit & Furry: Furry & Hurwitz. (*Nature*, 23rd Dec. 1944, Vol. 154, No. 3921, pp. 800–801: 13th Jan. 1945, Vol. 155, No. 3924, pp. 52–53.)

1248. Application of Statistics to Dielectrics.—Summers & Ross. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, pp. 405–407.) A summary was dealt with in 3622 of 1944.

1249. A Labour-Saving Method of Sampling.—Haldane. (*Nature*, 13th Jan. 1945, Vol. 155, No. 3924, pp. 49–50.)

1250. "Sampling Inspection Tables" [Book Notice].—Dodge & Romig. (*Journ. of Scient. Instr.*, Jan. 1945, Vol. 22, No. 1, p. 19.) Developed for use by the Bell Telephone System. For a paper by Dodge *see* 3298 of 1944.

1251. A New Method of Harmonic Analysis, *and* A New Mechanical Curve-Analyser.—Grützmacher: Kallenbach. (*Zeitschr. V.D.I.*, 1st April 1944, Vol. 88, No. 13/14, pp. 169–170: long summary of the papers referred to in 1731 of 1944.)

The mechanical analyser based on the new method is illustrated by the simplified model of Fig. 10. Two rollers *a* and *b* on a common horizontal spindle are driven by a motor. Roller *a* feeds forward the paper strip carrying the function-curve to be analysed: a fixed horizontal table *e* close over roller *b* has a slot over the whole length of *b* exposing its moving surface at its highest point. On this table is the recording paper in the form of a large disc: over the slot in the table, the paper is pressed on to the moving roller *b* by the small pressure roller *f*. Another small roller *d* forms a point of rotation for the paper, by pressing it down on to the table: the two rollers *f* and *d* are carried on a carrier *c* vertically above, and parallel to, the common spindle carrying the driving rollers *a* and *b*. This carrier can be slid to and fro, always parallel to the spindle, and is prolonged to form a pointer *g* over the paper strip bearing the curve under analysis: the carrier is adjusted by hand so that *g* follows the course of the curve. The initial point of the derived vector trace on the paper disc is taken at a point *A* (on the line joining the two pressure rollers *f* and *d*) obtained by setting the pointer *g* to the zero line of the curve under analysis. If a pencil, fixed rigidly to the table, is brought on to the paper disc at this point *A*, it will trace the required vector line. In the instrument as actually constructed the pencil records only the initial point *A* and the final point: then the line joining these two points gives the required partial-tone vector in amplitude and phase. Gearing is interposed between rollers *a* and *b*, of ratio variable up to 1 : 12, so that the first

12 harmonics can be determined. A first model gave results accurate within 1–2% as to amplitude and within $n°–2n°$ as to phase, n being the order of the harmonic.

1252. "Basic Mathematics for Engineers" [Book Reviews].—Andres, Miser, & Reingold. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 267–268: *Journ. Franklin Inst.*, Nov. 1944, Vol. 238, No. 5, p. 382.)

1253. Pity the Poor Student! [Review of "Heaviside's Operational Calculus Made Easy" and "Radio Technique"].—Turney: Mills. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 10.)

Previous reviews were referred to in 258 of January and 632 of February, respectively. The present reviewer pleads for "a new outlook, and the preparation and publication of books over which the author has sweated, and over which the student must be prepared to sweat in his turn: then we shall be beginning to train engineers": *cf.* Preisman, 3677 of 1944.

1254. "Ultra-High-Frequency Radio Engineering" [Book Review].—Emery. (*Wireless Engineer*, Feb. 1945, Vol. 22, No. 257, pp. 74–75.)

Among several points questioned by the reviewer is the apparent use of "ultra-high-frequency" to represent frequencies above about 30 Mc/s, embracing the bands of "very-high," "ultra-high," and "super-high" frequencies in what is, he mentions, the only classification which has so far received international agreement.

1255. The Royal Signals School of Signals.—(*Engineer*, 24th Nov. & 1st Dec. 1944, Vol. 178, Nos. 4637 & 4638, pp. 412–413 & 430–433.)

1256. The Conquest of Distance by Wire Telephony: a Story of Transmission Development from the Early Days of Loading to the Wide Use of Thermionic Repeaters.—Shaw. (*Bell S. Tech. Journ.*, Oct. 1944, Vol. 23, No. 4, pp. 337–421.)

1257. Modern Submarine-Cable Telephony and the Use of Submerged Repeaters.—Halsey. (*See* 1100.)

1258. Broadcasting in the U.S.S.R.—Machill. (*E.T.Z.*, 30th Dec. 1943, Vol. 64, No. 51/52, p. 675 onwards.) A brief summary is given in *Bull. Assoc. Suisse des Elec.*, 26th July 1944, Vol. 35, No. 15, p. S.25, and a long one in *Zeitschr. f. Fernmeldetechnik*, 3rd April 1944, Vol. 25, No. 2, pp. 38–39.

1259. The British Council: Annual Report.—British Council. (*Nature*, 13th Jan. 1945, Vol. 155, No. 3924, pp. 58–60: long summary.)

1260. International Activities in Science.—Dale. (*Nature*, 9th Dec. 1944, Vol. 154, No. 3919, pp. 724–726.)

1261. An International Science Cooperation Service [should be set up by United Nations, parallel with I.L.O. & Similar Bodies].—Needham. (*Nature*, 25th Nov. 1944, Vol. 154, No. 3917, pp. 657–660.) For a leading article, under the title "Dissemination of Scientific Information," *see* pp. 649–652.

1262. The Engineer - Consultant: Should there be an Engineer in the President's Cabinet?—Fruend. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, p. 409: summary only.)

1263. Retain Germany's Peace-Time Industry! [Joint Statement by Presidents of Five American Engineering Societies].—(*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, pp. 393–394.)

1264. Science and Industry in National Security.—Patterson. (*Nature*, 23rd Dec. 1944, Vol. 154, No. 3921, pp. 785–788.) Address by the U.S. Under-Secretary for War.

1265. The Contribution of Science to Civilisation [Reviews of "Science and the Future" and "The Impact and Value of Science"].—Trueman: Hill. (*Nature*, 11th Nov. 1944, Vol. 154, No. 3915, pp. 589–590.)

1266. Scientific and Industrial Research: VI—(*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 407–410.) For previous parts *see* 301 of January.

1267. The Philosophy of Research [Symposium on "Organisation, Direction, and Support of Research": Summaries of Papers].—American Philosophical Society. (*Nature*, 26th Aug. 1944, Vol. 154, No. 3904, pp. 263–265.)

1268. The Organisation of Experimental Research [including Statistical Quality Control and Statistical Methods in the Laboratory].—Radley. (*See* 1122.)

1269. Research and Sense [Leading Article on Ricardo's Address on "Applied Research", *ibid.*, pp. 368–369 & Previous Issues].—Ricardo. (*Engineer*, 10th Nov. 1944, Vol. 178, No. 4635, pp. 374–375.)

1270. Military Research Fellowships in the Physical Sciences ["Critical Survey of the Military-Scientific Effort, with a View to Charting a Prudent Peace-Time Course": Editorial].—Harnwell. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 239–243.)

1271. The "Frank B. Jewett" Post-Doctorate Fellowships in Physical Science.—American Telephone & Telegraph. (*Nature*, 25th Nov. 1944, Vol. 154, No. 3917, pp. 665–666.)

1272. Excerpts from *The London Times* [on the I.C.I. Research Fellowships].—I.C.I. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 278–279.) *See* also 3697 of 1944.

1273. "Industrial Research under Free Enterprise" [Correspondence on Ruthenberg's Address (3700 of 1944): Protests & Praise].—Ruthenberg. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, p. 353: Nov. 1944, No. 11, pp. 422–423.)

1274. Freedom in Science [Correspondence on Bridgman's Article, 298 of January].—Ross: Bok: Bridgman. (*Science*, 8th Sept. 1944, Vol. 100, No. 2593, pp. 217–218.)

1275. Incentives for Science [Faraday Medal Presentation Response].—Langmuir. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, pp. 363–364.)

1276. Technical Civil Service [Letter on the Institution of Professional Civil Servants' Report on Post-War Reconstruction].—Crampton. (*Engineer*, 24th Nov. 1944, Vol. 178, No. 4637, p. 416.)

1277. The Technician in the Civil Service [and a Recent Memorandum of the Institution of Professional Civil Servants].—(*Engineering*, 3rd Nov. 1944, Vol. 158, No. 4112, pp. 351–352.)

1278. Status of Professional Civil Servants [Summary of Two Pamphlets].—Institution of Professional Civil Servants. (*Nature*, 9th Dec. 1944, Vol. 154, No. 3919, pp. 743–744.)

1279. Collective Bargaining and the Engineer. —Hawkins. (*Review Scient. Instr.*, Sept. 1944, Vol. 15, No. 9, pp. 219–223.)

1280. Collective Association of Engineers [advocated by President, A.I.E.E.].—Powel. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 279–280.)

1281. The Organisation of the Engineering Profession [Leading Article on Chairman's Address, North Western Centre of I.E.E.].—Kidd. (*Engineering*, 27th Oct. 1944, Vol. 158, No. 4111, pp. 331–332.)

1282. Professional Service in Universities, Technical Colleges, and Industry [Letter prompted by Leading Article on "Professional Institutions": Steps taken by the Joint Council of Professional Scientists].—Pickard. (*Nature*, 30th Dec. 1944, Vol. 154, No. 3922, p. 832.)

1283. "A More Perfect Union": Contribution to the Correspondence dealt with in 295 of January & Back References [and the Desirable Attributes for the "New" American Institute of Physics].—Wildhack: Harnwell. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 271–272.)

1284. Twenty-Fifth Anniversary of the Wireless Section: Abstracts of Addresses at the Commemorative Meeting.—(*Journ. I.E.E.*, Part III, Sept. 1944, Vol. 91, No. 15, pp. 100–104.)

1285. I.R.E. Constitutional Amendment Section: H. P. Westman's Petition [for "Uniform Level" System of Fees, regardless of Grade (excepting Students)].—I.R.E. (*Proc. I.R.E.*, Oct. & Nov. 1944, Vol. 32, Nos. 10 & 11, pp. 639–640 & 713.)

1286. Commutation of Annual Subscriptions [Further Correspondence: *see* 313 of January].—Unna: Heron. (*Nature*, 9th Dec. 1944, Vol. 154, No. 3919, p. 740.)

1287. Discussions on "The University Education and Industrial Training of Engineers, with Particular Reference to Telecommuncations" [2546 of 1943].—Willis Jackson. (*Journ. I.E.E.*, Part III, Dec. 1944, Vol. 91, No. 16, pp. 208–217.)

1288. Post-War University Education [Critical Survey of the British Association Committee's Report].—Horton. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 414–416.)

1289. Post-War Curriculums in Electrical Engineering.—Kloeffler. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, pp. 364–367.)

1290. Discussion on "Physics and the Scientific Instrument Industry" [3323 of 1944: the Danger of the Modern Tendency to Load the Schoolboy with Theoretical Physics divorced from Personal Experiment].—Hansel: Philpot. (*Proc. Phys. Soc.*, 1st Nov. 1944, Vol. 56, Part 6, No. 318, p. 396.)

1291. Education and Training [of Wireless Technicians & Craftsmen: Note on Second Part of British I.R.E. Report on Post-War Development].—British I.R.E. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 8.) For a "Monthly Commentary" note *see* p. 1.

1292. War Surplus Disposal [Support for Cazaly's Suggestion (641 of February) and Its Extension].—Clinch: Cazaly. (*Wireless World*, Jan. 1945, Vol. 51, No. 1, p. 27.)

1293. Flying Radiomen of the Ferrying Division: Duties and Training of Flight Radio Operators of the Ferrying Division, ATC, AAF.—Haines. (*QST*, June 1944, Vol. 28, No. 6, pp. 16–19 and 82, 84.)

1294. A Flexible Code-Table Circuit: a Simple Wiring Scheme providing Many Circuit Combinations [and providing for Segregation of Students according to Ability, etc.]. —Appleton. (*QST*, April 1944, Vol. 28, No. 4, pp. 47–49.)

1295. Radio Amateurs help the War [Part played by Amateurs in the F.C.C. Radio Intelligence Division].—F.C.C. (*Sci. News Letter*, 11th Nov. 1944, Vol. 46, No. 20, p. 316.)

1296. Scientific Literature for Liberated Europe: an Appeal.—Assoc. of Scientific Workers. (*Nature*, 23rd Dec. 1944, Vol. 154, No. 3921, p. 794: *Engineer*, 22nd Dec. 1944, Vol. 178, No. 4641, p. 483.) *Cf.* 967 of March.

1297. B.S.I. Specification in Basic [Experiment in translating Portland Cement Specification into Basic English].—British Standards Institution. (*See* 1126.)

1298. Information Departments.—(*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4119, p. 492.) For the erroneous prejudice against including trade catalogues, and even house journals, in libraries, *see* p. 494 (G. K. Wilkie).

1299. The Expanding Library: "The Scholar and the Future of the Research Library: a Problem and Its Solution" [based on the Use of "Micro-Cards," with Catalogue Entry & Abstract on One Side, and on the Other the Whole Text of Book or Paper in Micro-Print, by "Readex" or Other Process: Elimination of Disadvantages of Microfilms: Book Review].—Rider. (*Nature*, 25th Nov. 1944, Vol. 154, No. 3917, p. 655.)

1300. "Die Dokumentation und ihre Probleme" [Collection of Papers read at the First Meeting: Book Review].—German Society for Documentation. (*Zeitschr. V.D.I.*, 4th March 1944, Vol. 88, No. 9/10, pp. 125–126.)

1301. A Simple Microfilm Reader [folding down into a Thin Cardboard Box: primarily for use in the Field].—American O.W.I. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, p. 220.)

1302. Drawing-Office Practice in relation to Interchangeable Components.—Gladman. (*Engineering*, 1st Dec. 1944, Vol. 158, No. 4116, p. 433: summary only.) For a leading article *see* issue for 8th December, No. 4117, pp. 451–452, under the heading "Symbols on Drawings." For a longer summary see *Engineer*, 1st Dec. 1944, Vol. 178, pp. 441–442.

1303. Graphical Symbols brought Up-to-Date: Telegraph, Telephone, Radio [including Symbols for R.F. Cable].—Heard. (*Indust. Standardization* [New York], Nov. 1944, Vol. 15, No. 11, pp. 224–225.) *Cf.* 970 of March.

1304. Personality and Draughtsmen [and the Killing of Incentive].—Watson. (*Engineer*, 22nd Dec. 1944, Vol. 178, No. 4641, p. 495.)

1305. "Patent Law" [for Chemists, Engineers, & Students: Book Review].—Biesterfeld. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 717–718.)

1306. Patent Law and the Engineer.—Emmerton. (*Engineer*, 22nd Dec. 1944, Vol. 178, No. 4641, pp. 493–495.)

1307. Scientific Research and Patents [Leading Article].—(*Nature*, 11th Nov. 1944, Vol. 154, No. 3915, pp. 587–589.)

1308. Physics in Industry [Note on Symposium in Glasgow].—Marskell & others. (*Journ. of Scient. Instr.*, Jan. 1945, Vol. 22, No. 1, p. 20.)

1309. Electronics in Industry [Address to Nat. Electronics Conference: including Some Factors causing Long Delay between Laboratory Development and Commercial Utilisation, and the Effect of the War on These Factors: Valve Life & Variation in Characteristics remain].—White. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, p. 419: summary only, in survey of the Conference.)

1310. Application of Electronics to Aircraft Flight Control.—Gille & Kutzler. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 849–853.) A summary was dealt with in 690 of February. *Cf.* Halpert & Esval, "Electric Automatic Pilots for Aircraft," pp. 861–866.

1311. Aircraft Electrical Horizons [with a Paragraph on Communication Equipment].—Godsey & others. (*Elec. Engineering*, Nov. 1944, Vol. 63, No. 11, Transactions pp. 821–824.)

"Thoughtful study will eliminate many pounds of equipment weight and much aerodynamic drag from external antennas . . ."

1312. Electronics in Instrumentation ["provides means of making Certain Measurements More Accurately: New Forms of Primary Measuring Elements & Circuits: New Methods of Indicating, Recording, & Controlling"].—Middel. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 9–16.)

Including the "polaroid" servo mechanism (2426 & 4083 of 1944), gas analysis (including "the new method depending on the change in the velocity of sound with changes in molecular weight"), pressure and flow gauges (including the "Wiggletron" valve with pressure-varied grid/cathode spacing), photoelectric pyrometry, self-balancing potentiometers (including the "Pyrotron", primarily for temperature control), etc.

1313. Measuring Taper and Tension: Application of the Electric Gauge to Production-Control Measurements.—Catlin. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 19–20.)

1314. Measuring Arc Duration [the Arc-Interval Timer, a New Instrument for Development Work on Industrial-Control & Switch-Gear Equipment].—Quill. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 22–24.)

1315. Equipment to test Measuring Devices [and Their Component Parts, for Quantity Production: Types of Magnetometer: Coil Testing: Tachometer Testing: the Photoelectric Decelerometer: etc.].—Princi. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 25–29.)

1316. Analysing Conveyor Production [Development of the Conveyor Analyser, with Strip-Chart Recorder].—Knauth. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 32–35.)

Designed primarily for use in a radio-transmitter line, so that several usual scanning methods were out of the question: for instance, unfinished radio

chassis are full of holes and are thus unsuited to photoelectric scanning: they are substantially non-magnetic: they are mounted on swivelling positioners, so that the mechanical wiper cannot be used. A weighing method was therefore adopted.

1317. Testing Insulation of Low-Voltage Thin-Walled Cable [Water Sparker Equipment with Electronic Control, for Rapid and Efficient Testing].—Anderson. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 38–39.)

1318. Electronic Counter and Tachometer [for Production Testing of Coasting Revolutions of Solenoid-Brake-Equipped Aircraft Motors: Thyratrons/Photocell Equipment].—Downie. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 50–52.)

1319. Testing Selenium Rectifier Cells [Wattmeter Method for Integrated Measurements, Oscilloscope Method for Dynamic Characteristics, Grading, Life Testing].—Schwanhausser. (*Gen. Elec. Review*, Nov. 1944, Vol. 47, No. 11, pp. 53–55.)

1320. The Sonigage [Supersonic Thickness-Measuring Instrument primarily developed for Inspection of Hollow Steel Propeller Blades].—Erwin. (*Engineering*, 22nd Dec. 1944, Vol. 158, No. 4199, pp. 487–488.)

1321. On the Theory of the Amplifying Machine, the "Amplidyne."—Sequenz. (*Elektrot. u. Masch:bau*, 14th April 1944, Vol. 62, No. 15/16, pp. 173–179.) Development of a short theory which fits in with American performance data.

1322. A New Electric Speed Regulator [primarily for Large Water Turbines: System based on the Frequency-Dependence of a Resonant Circuit, combined with Ferraris Discs].—Hirt & Gantenbein. (*Elektrot. u. Masch:bau*, 19th Feb. 1943, Vol. 61, No. 7/8, p. 85: summary only.)

1323. The New Siemens High-Precision Voltage Regulators [for Constancy within ± 1–0.25 ‰].—Ludwig: Burisch & Ludwig. (*Elektrot. u. Masch:bau*, 5th March 1943, Vol. 61, No. 9/10, pp. 105–106.)

1324. Electronic A.C. Power Regulator [Instantaneous & Independent of Frequency].—Wild & Cherry. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 280: short summary of Nat. Electronics Conference paper.)

1325. Physical Control Methods in the Steel Industry.—Barr & Pearson. (*Journ. of Scient. Instr.*, Jan. 1945, Vol. 22, No. 1, pp. 1–5.)

1326. The Elementary Skin-Effect [Theory, with Possible Application to Electro-Magnetic Defectoscopy].—Arkadiev. (*See* 1046.)

1327. Comparison of Surface Roughness of Very Highly Finished Plane Surfaces [and a Selenium-Cell Reflection-Process Instrument distinguishing Roughnesses corresponding to Profile Heights of 1–8μ].—Kluge & Bochmann. (*Zeitschr. V.D.I.*, 1st April 1944, Vol. 88, No. 13/14, pp. 179–181.)

1328. An Aural Surface-Comparator [Adaptation of Stethoscope gives Handy & Sensitive Comparator].—Cox. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, p. 219.)

1329. Ford Electronic [Electron Diffraction] Camera for Surface Analysis.—Ford Motor Company. (*Journ. Franklin Inst.*, Nov. 1944, Vol. 238, No. 5, p. 394: summary only.)

1330. The "Faxfilm" Method of Surface Inspection ["with Some of the Advantages of the Microphotograph without using Photographic Processes"].—McDill Laboratories. (*Engineering*, 1st Dec. 1944, Vol. 158, No. 4116, p. 437.)

1331. Continuous Hardening of Steel by the H.F. Process.—Ohio Crankshaft Company. (*Scient. American*, Oct. 1944, Vol. 171, No. 4, pp. 169–172.) *See* also 379 of January.

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1358. Production of the *Light Effect* under X-Rays [Extension, to X-Ray Irradiation, of the Work dealt with in 3344/5 of 1944].—

Joshi. (*Current Science* [Bangalore], Nov. 1944, Vol. 13, No. 11, p. 278.) *See* also Dec. issue, p. 330, for corrected title (as given above).

1359. MICROSCOPY WITH LIGHT, ELECTRONS, AND X-RAYS [Survey].—Preston. (*Journ. of Scient. Instr.*, Dec. 1944, Vol. 21, No. 12, pp. 205–213.)

1360. PHASE-DIFFERENCE MICROSCOPY [Applications to Examination of Bacteria, Homogenised Milk, etc.].—Richards. (*See* 1140.)

1361. SCREENS WITH UNEVEN SURFACES [Mean Brightness may be Many Times that of Plane Screen]. — Antonov-Romanovsky. (*See* 1145.)

1362. RESOLUTION LIMIT OF PHOTOGRAPHIC OPTICAL INSTRUMENTS.—Moroz. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th Dec. 1943, Vol. 41, No. 8, pp. 326–328: in English.)

1363. THE PHYSICAL AND PHOTOCHEMICAL BASIS OF VISUAL RESOLVING POWER: PART I—THE DISTRIBUTION OF ILLUMINATION IN RETINAL IMAGES.—Byram. (*Journ. Opt. Soc. Am.*, Oct. 1944, Vol. 34, No. 10, pp. 571–591.)

1364. VISUAL MEASUREMENTS OF QUANTUM FLUCTUATIONS: I—THE THRESHOLD OF VISION AS COMPARED WITH THE RESULTS OF FLUCTUATION MEASUREMENTS: II—FLUCTUATIONS WHEN THE EYE IS LIGHT-ADAPTED: III—THE DEPENDENCE OF THE VISUAL FLUCTUATIONS ON THE WAVELENGTH.—Brumberg, Vavilov, & others. (*Journ. of Phys.* [of USSR], No. 1, Vol. 7, 1943, pp. 1–8, 9–11, and 12–17: in English.) For corrections to formulae in I *see* inset at beginning of No. 3, Vol. 7.

1365. INTERFERENCE PHENOMENA IN THE CASE OF ČERENKOV RADIATION.—Frank. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th March 1944, Vol. 42, No. 8, pp. 341–344: in English.)

1366. PROOF OF THE PRESENCE OF OCTOPOLAR RADIATION BY THE ZEEMAN EFFECT OF CERTAIN HELIUM RAYS, *and* CALCULATION OF THE TRANSVERSE ZEEMAN EFFECT OF AN OCTOPOLAR RAY OF HELIUM.—Brochard & Jacquinot: Yvon. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 581–583: pp. 585–587.)

(i) "The rays studied should therefore be attributed to octopolar radiation, an example of which is thus given for the first time." They were excited by a 10 Mc/s oscillator delivering about 2 kW to the long tube employed. (ii) Calculations to decide between the above conclusions and possible alternatives.

1367. ROTATION OF POLARISATION PLANE OF "FORBIDDEN" LINES IN OUTWARD MAGNETIC FIELD, *and* POLARISATION OF LIGHT SCATTERED BY EXCITED ATOMS: *also* ON THE SCATTERING OF LIGHT IN LIQUIDS.—Herman: Ginsburg. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 30th Dec. 1943, Vol. 41, No. 9, pp. 369–371 & 10th Feb. 1944, Vol. 42, No. 4, pp. 164–167: 10th Feb. 1944, No. 4, pp. 168–171: all in English.)

1368. A NEW STANDARD OF WAVELENGTH [in the Infra-Red Region]. — Ponizovsky. (*See* 1129.)

1369. INTEGRATION OF LIGHT IN SPECTROGRAPHIC ANALYSIS [Short Survey of Previous Integrating Methods (Photocell combined with Hydrogen or Copper Voltameter, Ballistic Galvanometer, Neon Tube, etc: Photochemical Exposure Meters): the Writer's Photocell/Condenser-Discharge Circuit for Integration & Dosing: Application to Spectrographic Aanalysis].—Sedov. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th Dec. 1943, Vol. 41, No. 8, pp. 329–331: in English.)

Will "make it possible to base the determination of impurities upon the absolute blackening of the respective spectral lines," and is likely to be of value also when the method of direct photometrical measurement of spectral lines is applied.

1370. PHOTOELECTRIC METHOD FOR ESTIMATION OF ZINC CONTENT IN BRASS BY SPECTRUM ANALYSIS.—Hopstein & others. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th Jan. 1944, Vol. 42, No. 2, pp. 62–64: in English.)

1371. PHOTOELECTRIC & CAPACITANCE-CHANGE EQUIPMENT FOR THE BALANCING OF GYROSCOPES.—Carlstein. (*Bull. Assoc. Suisse des Élec.*, 26th July 1944, Vol. 35, No. 15, pp. 401–405: in German.) For a summary see *Zeitschr. V.D.I.*, 18th March 1944, Vol. 88, No. 11/12, pp. 160–161.

1372. A PORTABLE LIGHT-BEAM TRANSMITTER-RECEIVER: A COMPLETE BATTERY-OPERATED LIGHT SOURCE AND PHOTOTUBE AMPLIFIER FOR FIELD USE [Telephonic Range up to $\frac{1}{8}$ Mile, Blinker Range up to 12 Miles].—French. (*QST*, April 1944, Vol. 28, No. 4, pp. 22–25 and 88 & Front Cover.) For other light-beam work *see* pp. 39–40.

1373. THE USE OF COLUMBIA RESIN NO. 39 AS AN OPTICAL CEMENT [withstanding Sudden Large Temperature Changes].—Coles & others. (*Journ. Opt. Soc. Am.*, Oct. 1944, Vol. 34, No. 10, pp. 623–625.)

1374. THE "KODATRON" SPEEDLAMP.—Jones. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, pp. 16–18.)

1375. A HIGH-SPEED CINEMATOGRAPH CAMERA [taking 120 Pictures at Rates up to 1500 per Second: using High-Voltage Spark in Air].—Henry. (*Journ. of Scient. Instr.*, Aug. 1944, Vol. 21, No. 8, pp. 135–141.)

1376. ELECTRICAL PROBLEMS ASSOCIATED WITH RUBBER-TYRED VEHICLES.—Woods. (*Distribution of Elec.*, Jan. 1945, Vol. 17, No. 157, pp. 363–365.) With literature and patent references.

1377. THE SMITH-PUTNAM WIND-TURBINE [for 1000 kw: on Green Mountains, U.S.A.].—(*Elektrot. u. Masch:bau*, 3rd Sept. 1943, Vol. 61, No. 35/36, pp. 431–432: summary, from *Mech. Eng:g*, June 1941.)